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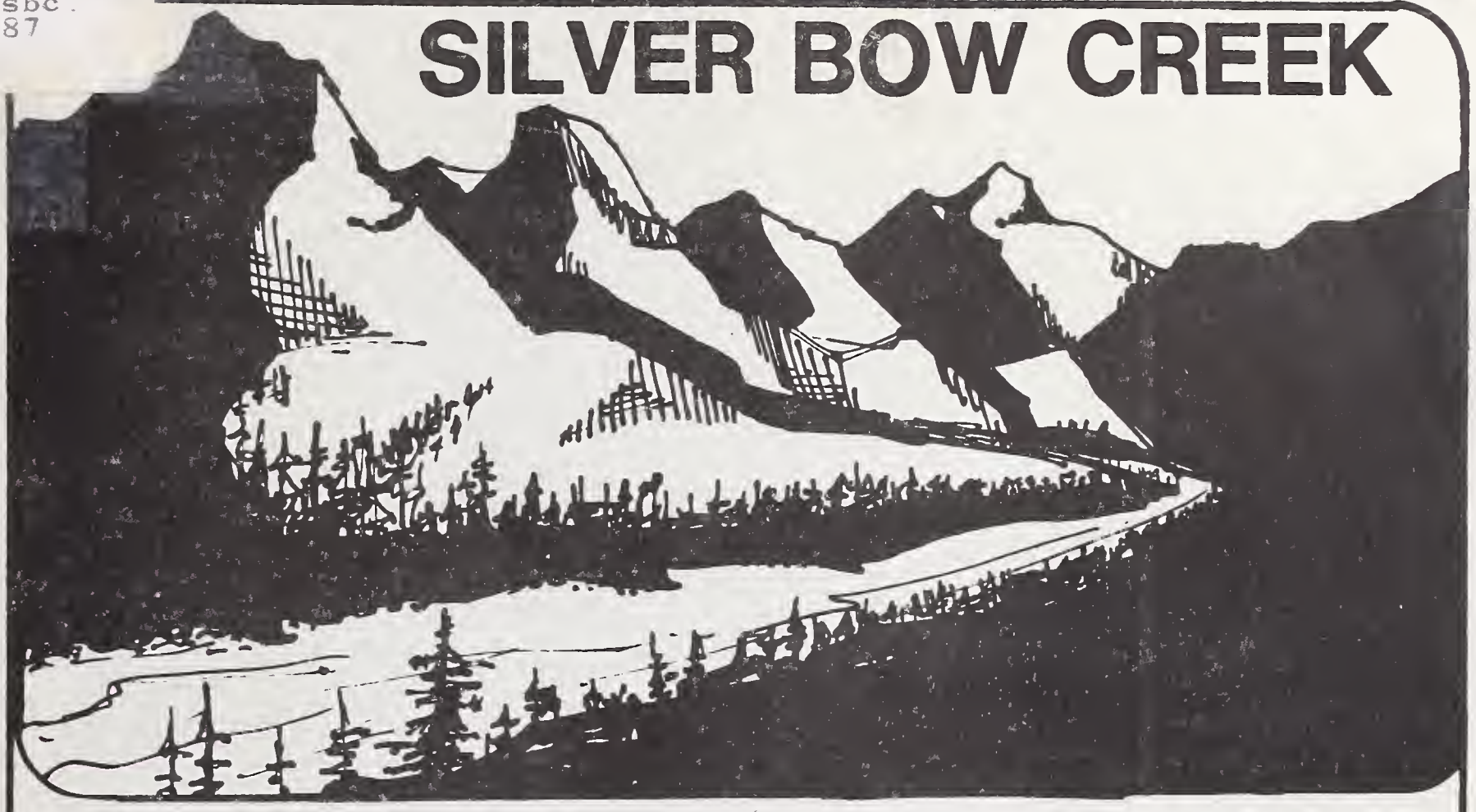

REMEDIAL INVESTIGATION FINAL REPORT

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SILVER BOW CREEK REMEDIAL INVESTIGATION
DRAFT FINAL REPORT

SUMMARY

Author(s) and Contributors

Robert Trout
Jay Cornish

Gordon Huddleston
Dave Tuesday
Clarence Whitworth
Sandra Fitch
Heather Johnson

Submitted to:

Solid and Hazardous Waste Bureau
Department of Health and Environmental Sciences
Cogswell Building
Helena, MT 59620

Submitted by:

MultiTech
A Division of MSE, Inc.
P.O. Box 4078
Butte, MT 59702

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ACKNOWLEDGEMENTS

MultiTech subcontracted the following Montana firms for portions of the Silver Bow Creek Remedial Investigation studies. They were major authors of, or contributors to, one or more of the eleven technical reports for the Silver Bow Creek Remedial Investigation:

- Stiller and Associates, Helena
- OEA Research, Helena
- Schafer and Associates, Bozeman
- Occusafe Inc., Butte
- Cashell Engineers, Butte

In addition, the USEPA Region VIII Bioassay Team conducted on-site tests and prepared the Bioassay Test Report (Appendix E, Part 2) of the Silver Bow Creek Remedial Investigation Final Report.

The following public agencies provided technical, editorial, and regulatory review comments and suggestions on draft reports prepared during this remedial investigation:

- Montana Department of Health and Environmental Sciences
- Montana Department of Fish, Wildlife and Parks
- Montana Governor's Office, Clark Fork River Basin Project
- United States Geological Survey
- United States Environmental Protection Agency

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PREFACE

Silver Bow Creek originates north of Butte, Montana and is a major tributary to the upper Clark Fork River. Mill tailings and other mining wastes in and near the creek contribute to substantial downstream contamination, particularly by potentially toxic elements: arsenic, cadmium, copper, lead, iron, and zinc. These elements and others were present in the mine ore and remain as by-products of the milling and smelting processes.

The history of mining in the Butte area began with the discovery of placer gold in Silver Bow Creek, in late summer of 1864. Several townsites and camps developed among the diggings. However, these operations were short-lived, and most of the miners left by 1869. Those who stayed began prospecting the quartz lode deposits of silver and the associated complex copper ores on the Butte Hill. Their efforts culminated in a silver rush, which began in the mid-1870's and revived the old camp. During that time world-class deposits of copper ore were identified. By 1881, Butte had become one of the nation's major mining centers; the district attained national dominance in copper mining by the mid-1890's and international prominence by the turn of the century. By 1915, Anaconda Copper Mining Company (ACM) led the industry. In 1955 ACM became The Anaconda Company. In 1977, Anaconda became a subsidiary of Atlantic Richfield Company (ARCO) and the name was changed to the Anaconda Minerals Company (AMC). By 1980, in response to a depressed copper market, AMC closed all the underground mines and continued active mining only in the Berkeley Pit (established in 1955). AMC closed the Berkeley Pit in 1982 and the East Berkeley pit in 1983.

In addition to mining, various ore processing facilities also operated in the Butte area. The first two mills were erected in 1874 to smelt gold and silver. Ten years later, Marcus Daly, one of the founders of the Anaconda Copper Mining Company, built a copper smelter 27 miles west of Butte and planned the city of Anaconda. The Anaconda Smelter was moved to a new location in the city in 1900, and operated from 1903 to 1980.

The history of over 100 years of continuous mining and related activities changed the area's natural environment greatly. Early mining, milling, and smelting wastes were dumped directly into Silver Bow Creek and transported downstream to the Clark Fork River. In 1911, the first treatment pond was built by the Anaconda Copper Mining Company near Warm Springs, Montana, to settle out wastes from Silver Bow Creek before the water was allowed to move on. In 1916 and 1959, two more treatment ponds began operation. Silver Bow Creek continued to receive raw mining and milling wastes until 1972, when a treatment plant was added to the Weed Concentrator in Butte. Creek contamination problems were compounded by urban and domestic sewage, wood products treatment plants, and phosphate and manganese production facilities.

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In 1983, the U.S. Environmental Protection Agency (USEPA) designated Silver Bow Creek, contiguous portions of the upper Clark Fork River, and their environs as a high priority Superfund clean-up site. The site extends from Butte to Deer Lodge, Montana, generally following the course of Silver Bow Creek and the upper Clark Fork River. The site begins at the start of the Metro Storm Drain in Butte and ends at the Kohrs Bridge north of Deer Lodge.

The Silver Bow Creek Remedial Investigation (SBC RI) project consisted of coordinated individual studies to develop data on the extent and severity of contamination within the site. Results of the studies are reported in several volumes. This Summary Final Report discusses the entire project; final reports for each individual study have been issued as appendices to the Summary, as shown below:

- Surface Water and Point Source Investigation, Appendix A, Parts 1 and 2;
- Ground Water and Tailings Investigation, Appendix B, Parts 1-4;
- Warm Springs Ponds Investigation, Appendix C, Parts 1 and 2;
- Algae Investigation, Appendix D, Part 1;
- Vegetation Mapping, Appendix D, Part 2;
- Agriculture Investigation, Appendix D, Part 3;
- Macroinvertebrate Investigation, Appendix E, Part 1;
- Bioassay Investigation, Appendix E, Part 2;
- Fish Tissue Investigation, Appendix E, Part 3;
- Waterfowl Investigation, Appendix E, Part 4; and
- Laboratory Quality Assurance/Quality Control Program, Appendix F.

The Solid and Hazardous Waste Bureau (SHWB) of the Montana Department of Health and Environmental Sciences (MDHES) administered the USEPA appropriations to conduct this project. The Montana SHWB program manager was Mr. Michael Rubich. MDHES contracted with Multi-Tech in October 1984 to perform the SBC RI under contract No. 50341-1202503. The Project Manager at MultiTech was Mr. Gordon Huddleston.

MultiTech was assisted in the SBC RI work by Stiller and Associates of Helena and various other subcontractors. Several state and Federal agencies also provided technical information and expertise, including the USEPA bioassay team, the Montana Department of Fish, Wildlife and Parks, the Montana Water Quality Bureau, and the USEPA Montana Field Office.

Information developed in the SBC RI will be used in the next phase of the project, the Feasibility Study, to evaluate options for site remediation.

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EXECUTIVE SUMMARY

Remedial Investigations on a CERCLA Site are designed to develop data that, in conjunction with existing data, can be used (1) to describe the extent and severity of contamination of the site; and (2) to evaluate, select, and design remedial alternatives for the site.

Because of the size, complexity, and lack of background data on the Silver Bow Creek (SBC) site, a phased Remedial Investigation/Feasibility Study (RI/FS) approach was selected as the best way to reach project goals. On the SBC site this approach led to a Phase I Remedial Investigation (RI) which had the fundamental objectives of establishing a reliable data base for the site and providing a trend assessment of sources, pathways, and receptors of contaminants. This report and accompanying appendices are the result of the first-phase RI.

Data developed during this first-phase RI were used to describe as completely as possible the sources, pathways, and receptors of contaminants associated with the site. Where data are insufficient for site objectives, additional studies are recommended for Phase II Remedial Investigations.

ES-1.0 SOURCES

Contaminant sources to ground water and surface water were identified in the designated SBC RI area. Table ES-1 summarizes and ranks the contaminant sources during high and low flows on Silver Bow Creek. This table displays high flow/low flow dichotomy of contaminant sources. During low flows, most of the contaminant loading originates from the Metro Storm Drain (MSD) and upstream groundwater system(s), with lesser contributions from the municipal Sewage Treatment Plant (STP). The Browns Gulch and Missoula Gulch tributaries and bottom sediment re-entrainment predominate during high flows, although considerable contaminant loads also occur from the MSD and contaminated ground water. Figures ES-1 and ES-2 illustrate the sources of total loads of copper, zinc, iron, cadmium, arsenic, and lead delivered to Silver Bow Creek during the RI period (December 1984 to August 1985).

ES-1.1 GROUND WATER

Eight possible sources of contamination to ground water were identified within the RI study area. The characterized Silver Bow Creek sources were a buried tailings impoundment associated historically with the Parrot Smelter operations (located near the present Butte/Silver Bow City-County shop facilities),the Colorado Tailings, the Warm Springs Ponds, and Ramsay Flats. Potential sources include

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TABLE ES-1

RANKING OF CONTAMINANT SOURCES
TO SILVER BOW CREEK WITH LOADS IN LBS/DAY[a]

LOW FLOW RANK

	1	2	3	4
Cu	GW-02(4.9)	GW-01(3.5)	PS-08(1.9)[b]	SS-03(1.8)
Zn	GW-02(38.4)	GW-01(21.1)	SS-03(19.0)	PS-08(4.2)[b]
Fe	SS-03(10.7)	PS-08(9.4)[b]	GW-02(4.8)	--
As	GW-02(0.52)	GW-01(0.25)	PS-08(0.25)[b]	--
Pb	PS-08(0.18)	SS-03(0.06)	--	--
Cd	GW-02(0.08)	SS-03(0.07)	GW-01(0.06)	PS-08(0.03)[b]
Sulfate	PS-08(2302)	SS-03(1402)	GW-01(1381)	GW-02(1122)

HIGH FLOW RANK

	1	2	3	4	5
Cu	SS-12(8.3)	PS-08(5.9)[b]	GW-02(4.9)	SS-03(4.8)	GW-01(3.5)
Zn	PS-08(279.9)[b]	SS-03(40.3)	GW-02(38.4)	GW-01(21.1)	SS-12(9.8)
Fe	SS-12(229.7)	PS-04(39.4)	SS-03(31.7)	--	--
As	GW-02(0.52)	GW-01(0.25)	PS-08(0.25)[b]	--	--
Pb	SS-12(16.9)	PS-04(0.44)	PS-08(0.27)[b]	--	--
Cd	PS-08(0.59)[b]	SS-03(0.13)	GW-02(0.08)	GW-01(0.06)	--
Sulfate	PS-08(6040)[b]	SS-03(2540)	SS-12(2314)	GW-01(1381)	GW-02(1122)

Notes:

(a) Key GW-01 = Groundwater inflow between SS-05 and SS-06 (Montana Street)
GW-02 = Groundwater inflow between SS-06 and SS-07 (Colorado Tailings)
SS-03 = Metro Storm Drain
PS-04 = Missoula Gulch
PS-08 = Butte Sewage Treatment Plant
SS-12 = Browns Gulch

(b) PS-08(STP) "High Flow" represents ground-water pumping; "Low Flow" means all other samplings.

Maps 3-1 and 4-1 show sampling locations.

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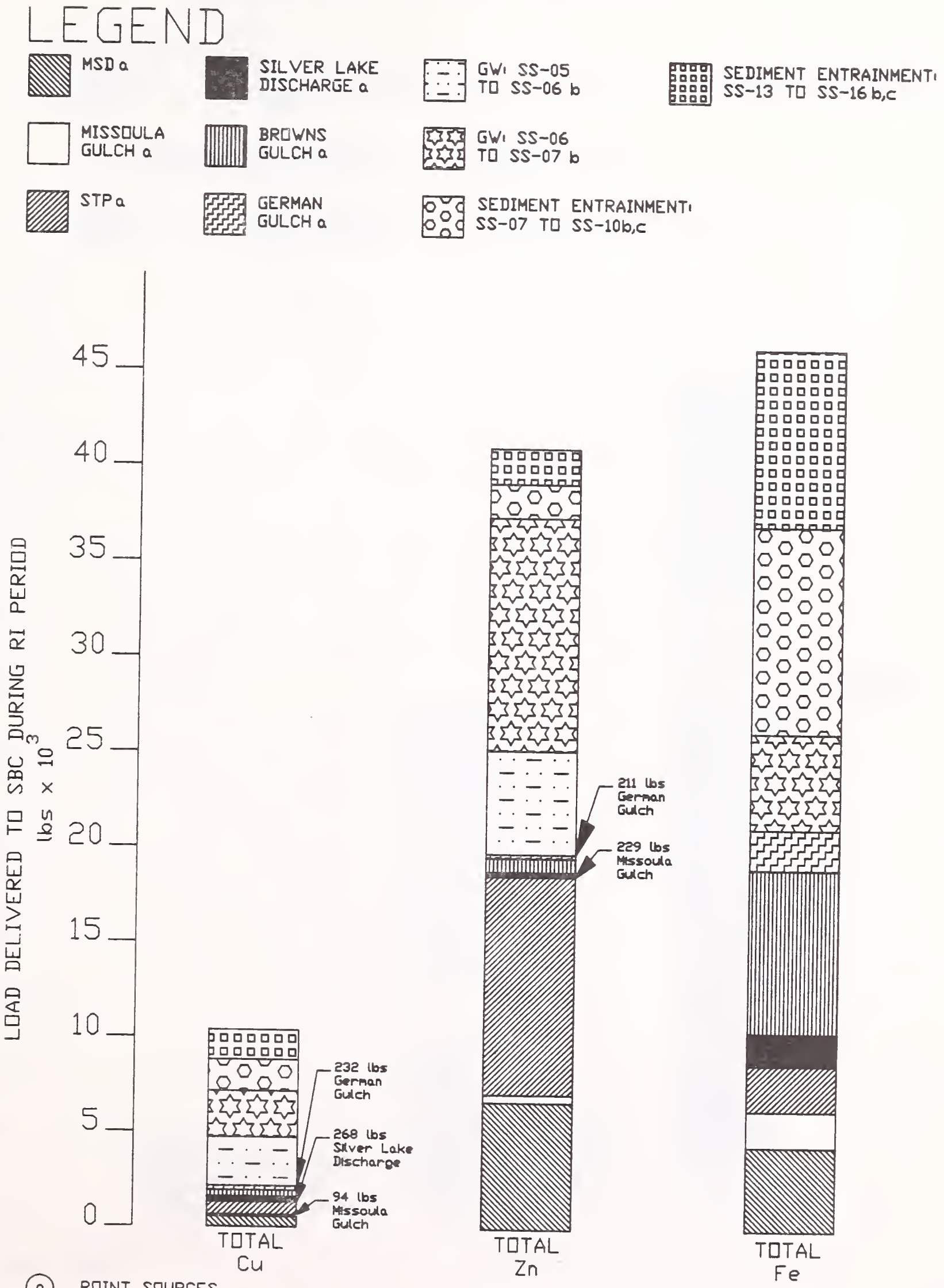
FIGURE ES-1
SOURCES OF TOTAL COPPER, IRON, AND
ZINC LOADS DELIVERED TO SILVER BOW CREEK
DURING THE PERIOD DEC. 1984 TO AUG. 1985.

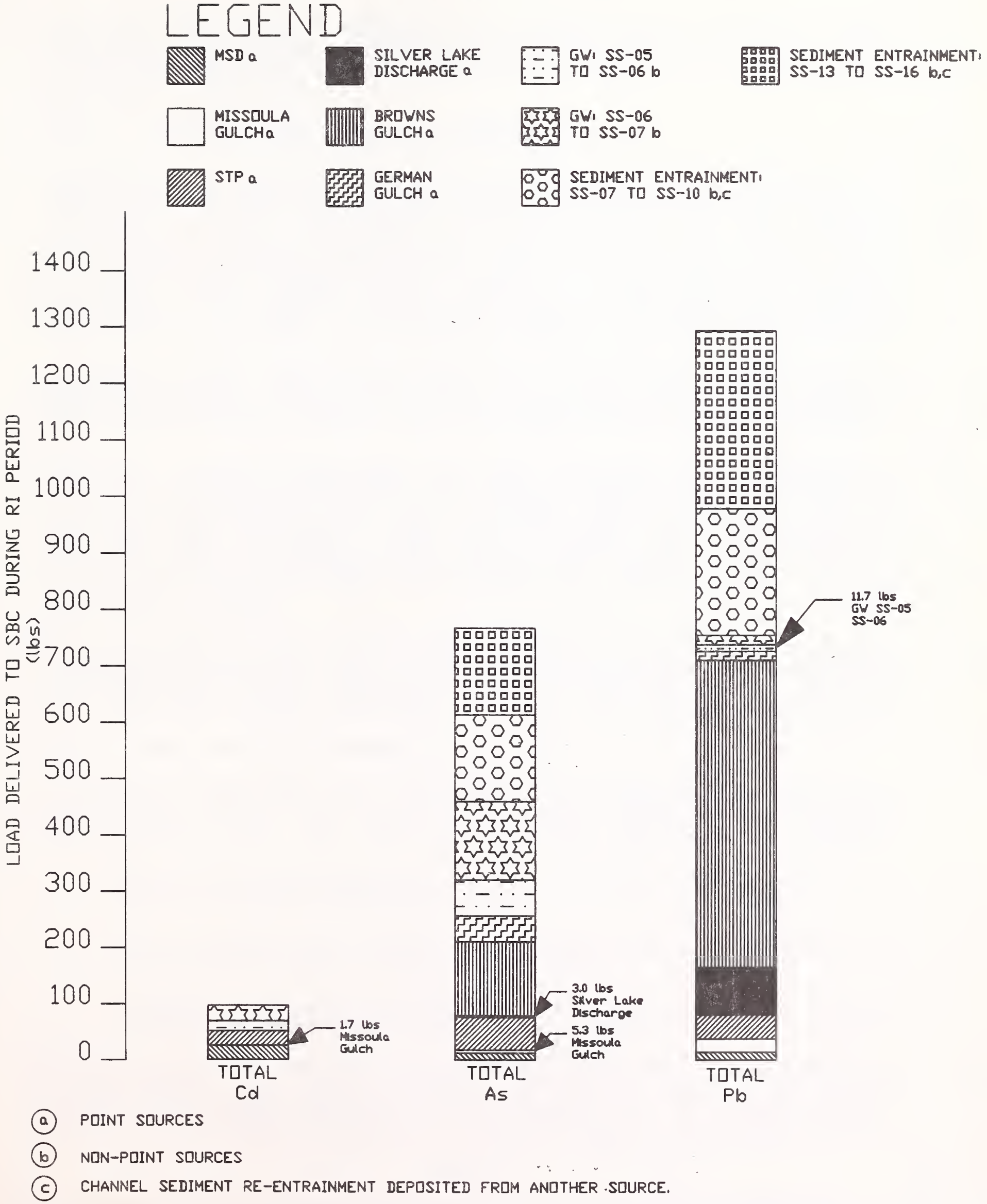


(a) POINT SOURCES

(b) NON-POINT SOURCES

(c) CHANNEL SEDIMENT RE-ENTRAINMENT DEPOSITED FROM ANOTHER SOURCE

FIGURE ES-2
SOURCES OF TOTAL CADMIUM, ARSENIC, AND
LEAD LOADS DELIVERED TO SILVER BOW CREEK
DURING THE RI PERIOD DEC. 1984 TO AUG. 1985.



(a) POINT SOURCES

(b) NON-POINT SOURCES

(c) CHANNEL SEDIMENT RE-ENTRAINMENT DEPOSITED FROM ANOTHER SOURCE.

the Weed Concentrator complex, the historic Butte Reduction Works tailings impoundments, fluvially deposited tailings, and the site of the Anaconda Pole Treatment Facility. These sources are briefly described in Table ES-2.

ES-1.2 SURFACE WATER AND POINT SOURCES

Measured point sources and non-point sources were the major contributors of contaminants to surface water. Point sources are surface flows with defined entry points into the Silver Bow Creek System. During low flows, the MSD and Missoula Gulch are the primary point sources causing degradation of Silver Bow Creek waters, while at higher flows, Browns Gulch becomes an additional significant point source of metals. During periods of ground-water pumping, the same can be said for the Butte Sewage Treatment Plant (STP).

Non-point sources are those lacking a well-defined entry point to Silver Bow Creek. Two major types of non-point sources were identified: ground-water inflows and stream bank/bottom sediment entrainment.

Table ES-3 briefly describes the major surface water contaminant sources. Lesser point sources of contaminants include the Montana Street and Kaw Avenue storm drain outfalls (TSS and metals); Montana Post and Pole Treatment seep (oil, grease, pentachlorophenol); Ranchland Packing Company (high biological oxygen demand organic wastes); and Stauffer Chemical Company seep (particularly sulfate and fluoride ions).

During the SBC RI, the Silver Lake discharge (a good quality bicarbonate water with low metals concentrations) diluted the contaminants in Silver Bow Creek. However, operation of the concentrator in Butte reduces or eliminates this discharge and its diluting effect.

ES-1.3 WARM SPRINGS TREATMENT PONDS (WSP)

The Warm Springs Ponds are a potential contributor of contaminants to the upper Clark Fork River. The three concerns for surface-water contamination from the Warm Springs Ponds are as follows:

- The flow-through of certain heavy metals and sulfate ion to the upper Clark Fork River;
- The potential of the filled-in ponds acting as a source of such contaminants in the future; and
- Present diversion of untreated Silver Bow Creek waters around the ponds during high-flow events.

During the SBC RI, a low-water year, the ponds system removed 60-70% of the copper, iron, lead, and zinc, about 33% of the arsenic, and 90% of the cadmium delivered to the ponds by Silver Bow Creek. Except for low flows during the summer, approximately 40% of the

TABLE ES-2

SUMMARY OF CHARACTERIZED AND POTENTIAL SOURCES OF CONTAMINATION TO SITE GROUND-WATER IDENTIFIED DURING THE SBC RI

Potential Source	Type	RI Findings
Upper MSD (Parrot)	Buried Tailings	Subsurface material had very high levels of metals compared to background. Ground water in, beneath, and downgradient from tailings was degraded.
Weed Concentrator	Discharge of Process Waters	Not evaluated, but a potential source, and may have contributed to problems from buried tailings in MSD area.
STP Vicinity (Butte Reduction Works)	Buried Tailings	No site-specific tailings analysis. Ground water beneath and downgradient was severely degraded.
Colorado Tailings	Surface Tailings	Tailings had elevated metals and contaminated soils and ground water beneath (MBMG data). Metals concentrations in ground water increased to the northwest.
Anaconda Pole Treatment	Surface Soil Contamination	Surface soils had very high levels of arsenic. Ground water was not characterized.
Ramsay Flats	Surface Tailings	Tailings contained up to 60 times background metals. Surface salts contained very high concentrations of metals (up to 15% by weight). Underlying shallow ground water was degraded but, due to low gradients and transmissivity, did not move away from the site significantly.
Fluvial Tailings Along SBC and CFR	Surface Tailings	Tailings had elevated concentration of metals. Ground water was only locally affected by contaminants.
Warm Springs Ponds	Impounded tailings, precipitates, and sediments.	Waste material has highly elevated metals, and contaminated groundwater plume was detected. No measurable effect on the Clark Fork River was found. Measurable effects were detected on the Mill-Willow Bypass.

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TABLE ES-3

SUMMARY OF CHARACTERIZED AND POTENTIAL SOURCES OF CONTAMINATION TO SITE SURFACE WATER IDENTIFIED DURING THE SBC RI

Potential Source	Type	RI Findings
Metro Storm Drain (MSD)	Point Source	Although contributing only a minor fraction of the total SBC flow, the MSD delivered significant amounts of Zn, Cu, Fe, Cd, and sulfate. This source significantly degraded Silver Bow Creek water quality.
Missoula Gulch	Point Source	As part of the MSD system, Missoula Gulch also degraded SBC water quality disproportionately to its flow. During low flows Cu, Zn, Pb, and Cd were contributed. During high flows those four metals plus Fe, As, and total suspended solids (TSS) were contributed.
Browns Gulch	Point Source	During high flows, Browns Gulch contributed significant loads of TSS, Fe, As, and Pb.
Butte STP	Point Source	During normal operations, the plant discharges considerable amounts of total phosphorus and orthophosphate to Silver Bow Creek. During ground-water pumping, Zn and Cd loads in SBC increased significantly and sulfate loads increased slightly.
Montana Street to Colorado Tailings	Non-Point Source--Ground-Water Inflow	Ground water entering the SBC here was a major source of dissolved Cu, Zn, and As and was a significant source of Cd and sulfate.
Mill-Willow Bypass	Non-Point Source--Ground-Water Inflow	Contaminated ground water discharged into the Bypass, contributing Fe, sulfate, and Zn.
Colorado Tailings to Silver Bow Siding	Non-Point Source--Re-entrainment	Metals data from snowmelt and storm runoff events indicate significant re-entrainment of channel sediments occurred during high flows.
Ramsay Flats to Opportunity	Non-Point Source--Re-entrainment	Metals data from snowmelt and storm runoff events indicate significant re-entrainment of channel sediments occurred during high flows.

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contaminants delivered to the Warm Springs Ponds were not removed and continued into the Clark Fork River.

No evidence was found during the RI that the ponds act presently as a source of contaminants. However, the long-term (>100 years) view must recognize the probable reduction in treatment efficiency as the ponds fill with sediment. When the ponds fill, they may begin to act as a source of contamination through gradual erosion of the previously deposited material.

The ponds are not designed to contain major floods. Consequently, a bypass channel has been constructed upstream of the Warm Springs Ponds; this channel is designed to divert flows exceeding 700 cfs around the ponds and directly into the Mill-Willow Bypass. These flood waters, containing high concentrations of metals, continue unimpeded and untreated into the Clark Fork River. Accumulation of debris on the trash racks of the diversion ditch headgate system can result in failure of the dike constructed at the mouth of the bypass channel. This blockage of the trash racks can result in dike failure at flows much less than 700 cfs; one such event occurred during the RI and may occur as frequently as once per year.

Although unlikely, catastrophic flooding or earthquake could cause Warm Springs Ponds embankment failure, resulting in release of precipitated and adsorbed metals into the Clark Fork River. Previous geotechnical investigators have concluded that flows greater than 4000 cfs on Silver Bow Creek could result in failure of the diversion headgate/upper pH shack structure; the 100-year flood event magnitude has been estimated to be 3600 cfs. The consequences of a 4000 cfs flood could include release of most of the waters into the Mill-Willow Bypass. A similar outcome could result from a Richter magnitude 6.9 earthquake along the Continental Fault, located directly east of Butte.

ES-2.0 PATHWAYS

ES-2.1 GROUND WATER PATHWAYS

Ground water containing various dissolved and suspended pollutants were produced from the characterized and potential SBC RI waste sources by surface water infiltrating downward through the sources, and/or by non-contaminated ground-water contacting the sources. Once entrained in the aquifer, the pollutants were distributed to other components of the site ecosystem by discharge to surface water and by beneficial water use withdrawal from the aquifer.

Groundwater efficiency as a pathway was determined by site-specific factors. The physicochemical properties and concentrations of the contaminants were affected by the nature of the source, reactions occurring within the ground water, and aquifer ground-water interactions as they migrated away from the source. Contaminant plume

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distribution was affected by such hydrogeologic factors as flow gradient and lithology of the water-bearing strata, plus climatic factors such as precipitation amount, seasonal distribution, and evapotranspiration rates.

ES-2.2 SURFACE WATER PATHWAYS

Surface water in contact with a source can acquire dissolved and suspended contaminants. Such waters in turn can act as a pathway to receptors by discharge into downstream surface drainage channels, infiltration into the ground water, or by standing on land surfaces located adjacent to the source site.

During the SBC RI period the MSD, Silver Bow Creek, the Warm Springs Ponds, and the upper Clark Fork River were pathways for contaminant migration from identified sources to identified receptors. The MSD received and transported dissolved contaminants from ground water (see Tables ES-2 and ES-3) and solid contaminants from storm event runoff. Silver Bow Creek received and transported dissolved contaminants from several ground-water sources (see Tables ES-2 and ES-3) and solid contaminants from several point sources (see Table ES-3). The Warm Springs Ponds received contaminants from Silver Bow Creek and served as a pathway for contaminants to reach the upper Clark Fork River. The upper Clark Fork River in turn passed received contaminants downstream to off-site receptors.

For the identified contaminants, chemical and physical factors affected the efficiency of their transport. The major factors included pH, stream morphology, and temporal and spatial changes in flow.

ES-2.3 BIOLOGICAL PATHWAYS

Algae were identified as the only significant biological pathway for migration of contaminants from one system compartment to another within the SBC site. Evidence was collected during the RI which suggested that algae in the Warm springs Ponds played a role in the transport of contaminants through the ponds.

RI evidence indicated that tested terrestrial plants and wildlife vertebrate animals associated with the site were not acting as significant pathways for metal contaminant movement through the food chain. Direct ingestion of contaminated soils by livestock was identified as a potential concern.

ES-3.0 RECEPTORS

ES-3.1 WARM SPRINGS PONDS

The Warm Springs Ponds were constructed to control contaminated Silver Bow Creek waters that otherwise would adversely affect the

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upper Clark Fork River. The Warm Springs Ponds Investigation Report (Appendix C) discusses their role as both a source and receptor of heavy metals contamination within the study area.

Heavy metal contaminants contained in surface waters entering the ponds are trapped as deltaic deposits (in upper portions of Pond 3), precipitated as flocculated oxyhydroxides or carbonates by abiotic and possibly biologically mediated processes, and as biologically-incorporated deposits. Appendix C compared sediment heavy metal analyses against background concentrations from analyses of Glacial Lake Missoula sediments. Enrichment factors of 10 to 100 times, relative to the expected concentrations, were indicated.

ES.3.2 UPPER CLARK FORK RIVER

The upper Clark Fork River receives heavy metals-contaminated waters from two major sources. First, it receives dissolved and suspended contaminants from surface discharge from the Warm Springs Ponds. Secondly, the river receives untreated flood waters channeled through the Mill-Willow Bypass, plus some ground-water seepage into the Mill-Willow bypass channel from both the Opportunity and Warm Springs Ponds systems.

ES-3.3 FLORA

ES-3.3.1 Algae

The algae investigation (Appendix D, Part 1) provided literature- and field-based evidence that phytoplankton residing in the Warm Springs Pond system concentrated certain metals from the water during spring 1985. The particular taxa included six genera of green algae (e.g., Chlorophyta), plus one genus each of bluegreen (Oscillatoria sp.), diatomaceous (Synedra ulna), and euglenoid (Euglena sp.) algae. The mechanisms for metal uptake include passive adsorption to mucilaginous sheaths as well as metabolic absorption processes. A portion of the bioaccumulator algal biomass appears to remain in Pond 2 with the remainder transported to the upper Clark Fork River. A quantitative assessment of metals transport by algae was not an objective the SBC RI.

The algal communities situated between the confluence of Silver Bow and Blacktail Creeks and the Warm Springs Ponds have been slowly recovering over the past ten years, in part due to improved quality of the industrial and municipal waste treatment effluents discharged into upper Silver Bow Creek. If the limited evidence from the Warm Springs Ponds can be extrapolated to upstream algal sampling sites, then bioavailable forms of metals may be accumulated by algae in this stretch of the RI site as well.

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ES-3.3.2 Riparian Vegetation

The Riparian Vegetation Investigation report (Appendix D, Part 2) documented the identification and mapping of the plant communities in the Silver Bow Creek and upper Clark Fork River floodplains; these communities have been affected, to varying degrees, by industrial and municipal effluents discharged within the study area. Of particular interest were those heavy metal-tolerant communities growing on, or adjacent to, streambank/floodplain mill tailings deposits. The flora known to exhibit fair-to-moderate metals tolerance, and observed in the area, include tufted hairgrass (Deschampsia caespitosa), redtop bentgrass (Agrostis alba), inland saltgrass (Distichlis stricta) and scorpion plant (Phacelia hastata). In wetter areas, the list included certain sedge (Carex) and cattail (Typha) species. At less-contaminated sites, a more diverse and multi-layered shrub/tree community was occasionally observed; these communities included an overstory represented by such taxa as willows (Salix), alder (Alnus), and cottonwoods (Populus).

The above communities may absorb heavy metals from the soil solution, and may accumulate such contaminants in their above-ground and/or below-ground tissues. The flora may also receive surficially deposited fugitive dust or "rain splash" materials originating from the tailings area.

The riparian communities associated with Silver Bow Creek and the upper Clark Fork River have been significant receptors of waste and contaminants transported by Silver Bow Creek and the upper Clark Fork river. Approximately 1100 acres of riparian community areas have been inundated by waste materials which do not support vegetative growth. Additional areas have been affected by contaminant migration.

ES-3.3.3 Agricultural Soils and Crops

The Agriculture Investigation (Appendix D, Part 3) provided circumstantial evidence that approximately 5400 acres of land have been contaminated by heavy metals, to varying degrees of severity, by using Silver Bow Creek or Upper Clark Fork river water for irrigation. During the Phase One (reconnaissance level) investigations, 38 soil horizon and 18 plant samples were acquired at 16 sites. These sites belonged to six different landowners and were located between Rocker and Gold Creek, Montana. With one exception, these samples were acquired above (uphill) and below (downhill) apparently abandoned, and oftentimes breached, irrigation ditches.

The key findings that support the hypothesis of waterborne contamination (as opposed to airborne contamination) were as follows:

- Soil and plant heavy metal levels were more frequently elevated (i.e., were greater than the "expected" biogeochemical background levels) in the downhill than uphill sites;

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- The downhill contamination was particularly significant for total (strong acid-extractable) copper and zinc; this situation extended occasionally to include arsenic, cadmium, lead and (rarely) manganese. Such contamination in downhill soils commonly occurred to 24 inches, and was observed at depths up to 46 inches. Similar contamination in uphill soils (which also may have received smelter stack particulate fallout) was generally limited to the upper 6 inches of soils;

- Strongly positive statistical correlations existed between arsenic and cadmium; arsenic and lead; copper and manganese; copper and lead; and copper and zinc in soils. All of these elements were mined in the Butte District ores and were contained, to varying degrees, in the mineral processing (mine, mill, smelter) effluents released from the Butte-Anaconda operations; and

- Although vegetation growing on contaminated sites were accumulating elevated levels of metals (especially zinc), the concentrations were generally in the range that is non-toxic to livestock, unless such materials constitute their sole source of forage.

ES-3.4 FAUNA

ES-3.4.1 Aquatic Insects

Aquatic insects are responsive to pollution stress, as was demonstrated by the close association between improved water quality and increased number of taxa and diversity of insect communities observed within the RI study area (Appendix E, Part 1). Four key examples of this association are given below:

- Prior to 1981, the combination of heavy metals levels and organic/nutrient loading essentially precluded aquatic insect communities in Silver Bow Creek as far downstream as Miles Crossing; pollution stress apparently resulted also in depauperate communities as far downstream as east of Opportunity. Since then, more tolerant forms have begun recolonizing this stream reach. However, the degree of annual fluctuation in both organism density and biomass levels, as well as generally low diversity, indicate early stages of biological recovery.

- The apparent lack of significant pollution loading at the confluence of Mill and Willow Creeks (prior to entering the Bypass channel) is reflected in the greatest number of taxa and highest diversity value observed at any of the stations sampled to date.

- High density and biomass levels, but low diversity communities, of organic matter-tolerant caddis flies (especially Cheumatopsyche sp. and Hydropsyche sp.) plus Dipterans (Simulium sp.) exist immediately downstream from the Warm Springs Ponds discharge into the Clark Fork River.

ES-3.4.2 Fisheries

The RI has provided two lines of evidence that fish, particularly rainbow trout (Salmo gairdineri), are receptors of heavy metal contaminants present within (and downstream of) the study area. The USEPA Bioassay Testing Report (Appendix E, Part 2) and the Fish Tissue Investigation (Appendix E, Part 3) provide fisheries information.

During the 30-day flow-through bioassay tests, several run-off events occurred which exceeded the calculated chronic and acute levels of acid-soluble copper. Under certain conditions of concentration and exposure duration, particular stages of the trout life cycle (e.g. eyed egg through fingerlings) may be especially sensitive receptors of such heavy metal contaminants. However, the test organisms showed no measurable effect from these pollutant spikes.

Ten rainbow trout were collected from the wildlife ponds (situated between Warm Springs Ponds 2 and 3) and were analyzed for selected metals content, pentachlorophenol (PCP), and polychlorinated biphenyls (PCB). The results indicate bioaccumulation of copper and zinc (relative to their respective concentrations in water) in both muscle and liver, while cadmium appeared to be accumulating in the liver only. The organic contaminants were present at detectable levels but, similar to the metals, do not appear to represent a significant public health concern.

The recent improvement of the fisheries resource in the upper Clark Fork River is discussed briefly in the introduction of the bioassay report. Unfortunately, the recovery has not been uniformly successful. The decline in fish population density between Deer Lodge and Drummond, in comparison to the relatively high values (1500 to 2500 trout per mile) observed immediately downstream of the ponds, may be partially attributed to lower water quality. Pre-SBC RI water analyses revealed copper, iron, and zinc concentrations that exceeded the respective aquatic life protection criteria; copper levels appeared to be the most limiting. Consequently, fish population density was generally inversely related to ambient metal concentrations. This relationship may explain partly why no viable fishery exists from Butte to Warm Springs Ponds, due either to direct toxicity or lack of food sources caused by contamination.

ES-3.4.3 Waterfowl

The Waterfowl Investigation (Appendix E, Part 4) provides evidence that at least one heavy metal is accumulating in waterfowl residing

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in the wildlife management area of the Warm Springs Ponds. A total of 41 specimens were collected from the wildlife management area, while four additional waterfowl were collected from control areas. Muscle and liver tissue samples were analyzed for selected heavy metals content. In addition, five muscle and five liver samples were extracted and analyzed for PCB and PCP levels.

The metals results indicate that only cadmium was significantly elevated above background levels in liver tissue, but not in muscle tissue. None of the other trace elements were found to exceed background levels in either tissue type. However, copper and zinc were found to collect preferentially in liver (as opposed to muscle) tissue. Zinc also appeared to be distributed differently in muscle tissue by age, sex, and taxonomic subfamily group.

PCP was detected in muscle and particularly in liver tissues. The concentrations measured do not appear to represent a significant public health concern. Three of the four muscle tissues from wildlife ponds' birds showed lipid-based residue concentrations of PCB exceeding the USDA food standard of 3.0 ppm; the other sample and off-site sample had PCB levels less than this standard. The PCB does not appear to be differentially distributed between muscle and liver tissues, nor do PCB levels appear to be related to PCP levels found in the waterfowl tissues.

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1.0 INTRODUCTION

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA--P.L. 96-510) requires the U.S. Environmental Protection Agency (USEPA) to identify, list, investigate, and clean up uncontrolled hazardous waste sites not regulated by the Resource Conservation and Recovery Act (RCRA--P.L. 94 580) or the Toxic Substances Control Act (TSCA--P.L. 94-469).

In 1982, the USEPA designated Silver Bow Creek, contiguous portions of the upper Clark Fork River, and their environs as a high priority CERCLA (Superfund) site. This site, located in southwest Montana in the Columbia River Basin, extended from the confluence of the Metro Storm Drain (MSD) and Blacktail Creek in Butte, Montana to the Kohrs Bridge, north of Deer Lodge, Montana. The site was listed by the USEPA because of the presence of contaminants within the aquatic system at levels potentially injurious to people and the environment. Contaminants identified by the USEPA included arsenic, cadmium, copper, iron, lead, zinc, manganese, molybdenum, aluminum, and silver (CH_2M Hill 1983).

CERCLA allows the USEPA to enter into cooperative agreements with individual states to administer the Superfund program within the state. Montana entered into such an agreement in 1984 for the Silver Bow Creek Superfund site. The state agency responsible for

administering this program is the Solid and Hazardous Waste Bureau (SHWB) of the Montana Department of Health and Environmental Sciences (MDHES) in Helena.

MDHES contracted MultiTech of Butte to conduct a remedial investigation (RI) as part of an established step-by-step process that leads to clean-up of Superfund sites. This process, required by CERCLA, is summarized in Figure 1-1 as it applied to the Silver Bow Creek (SBC) site.

1.1 REMEDIAL INVESTIGATION PROCESS

The language of CERCLA and the National Contingency Plan (NCP) require that Remedial Investigations (RIs) meet specific objectives. The NCP defines Remedial Investigation as follows:

> Remedial Investigation is a process undertaken by the lead agency (or responsible party if the responsible party will be developing a clean-up proposal) which emphasizes data collection and site characterization. The RI is generally performed concurrently and in a interdependent fashion with the feasibility study. However, in certain situations the Agency may require potential responsible parties to conclude initial phases of the RI prior to initiation of the feasibility study. A RI is undertaken to determine the nature and extent of the problem presented by the release. This includes sampling and monitoring, as necessary, and includes the gathering of sufficient information to determine the necessity for and proposed extent of remedial action. Part of the RI involves assessing whether the threat can be mitigated or minimized by controlling the source of the contamination at or near the area where the hazardous substances or pollutants or contaminants were originally located (source control remedial actions) or whether additional actions will be necessary because the hazardous substances or pollutants or contaminants have migrated from the area of their original location (management of migration) (NCP; 40 CFR 300).

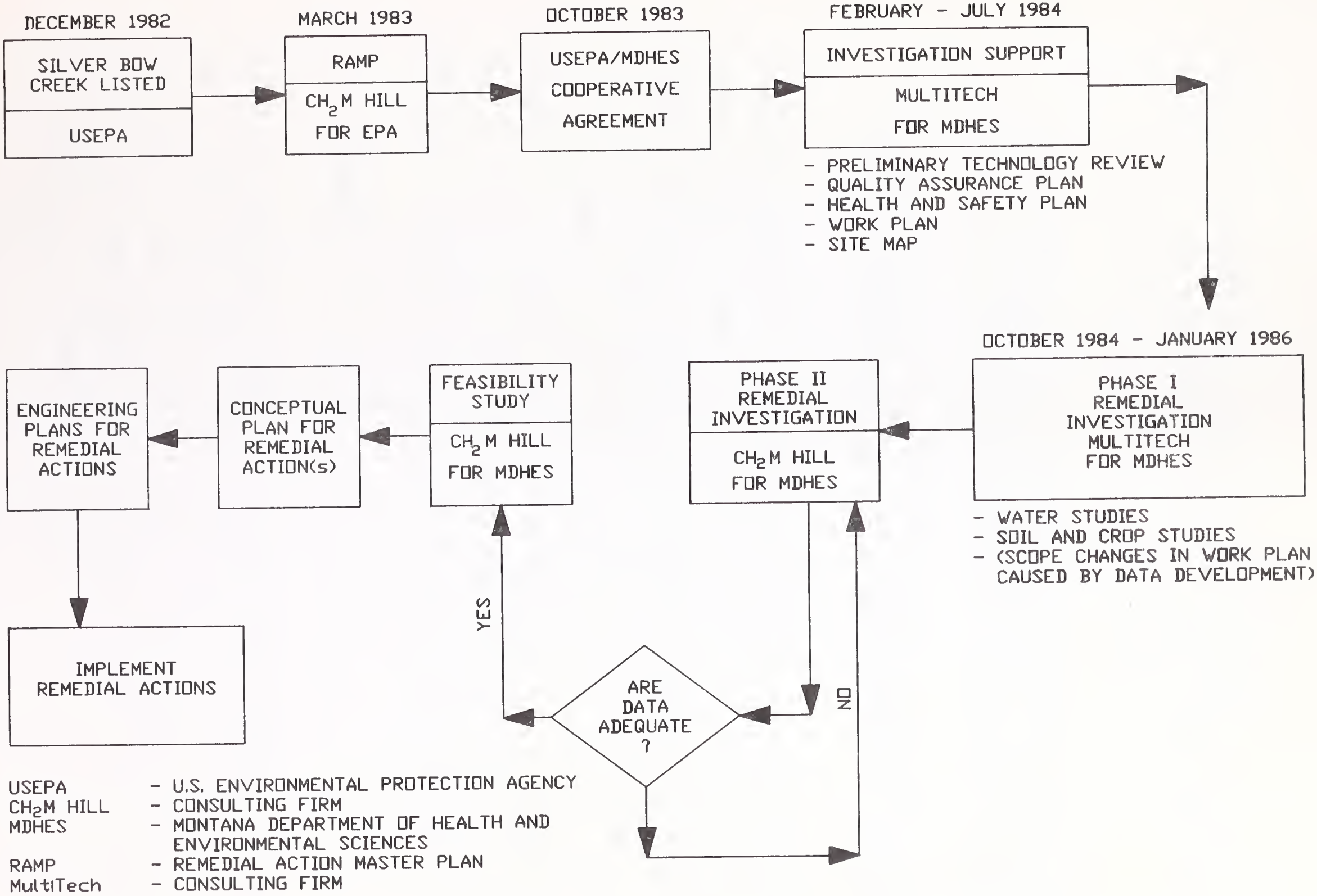


FIGURE 1-1 -- SILVER BOW CREEK REMEDIAL INVESTIGATION PROCESS

The RI of a CERCLA site "emphasizes data collection and site characterization." On the Silver Bow Creek site these NCP directives were translated into the following objectives:

- Develop data, that in conjunction with existing data, could be used to describe the extent and severity of contamination of Silver Bow Creek and the upper Clark Fork River. These data were for use in the performance of an endangerment assessment; and
- Develop data, that in conjunction with existing data, could be used to evaluate, select, and design remedial alternatives (MultiTech and Stiller and Associates 1984a).

As shown in Figure 1-1, the Remedial Investigation/Feasibility Study (RI/FS) Process leads to the development and implementation of remedial actions to reduce or eliminate contaminant problems at a site. The Remedial Investigation part of the RI/FS process is the data development stage. The Feasiblity Study part of the RI/FS process is the stage where the RI data are used to evaluate the risk to people and the environment and where RI data are used to identify, evaluate, rank, and select alternative remedial actions.

1.1.1 SBC RI

Because of the size, complexity, and lack of adequate background data on the SBC site, a phased RI/FS approach was selected as the best way to reach the project goals. The Feasibility Study (FS) for the site was planned to follow the RI rather than be performed concurrently, as recommended in the NCP. This approach was chosen

because the size and nature of the site required a phased RI for focusing site characterization efforts. A significant drawback in this approach was that data required for the FS could only be postulated, and once the FS was initiated, significant data gaps might still be identified. Planning for the SBC RI included a review of the existing data and potential remedial actions (Multi-Tech and Stiller and Associates 1984b) to minimize data gaps at the end of the RI effort.

On the SBC site this phased approach also lead to a Phase I Remedial Investigation which had the fundamental objectives of establishing a reliable data base for the site and providing a trend assessment of sources, pathways, and fate (receptors) of contaminants. This report and accompanying appendices are the results of this first phase.

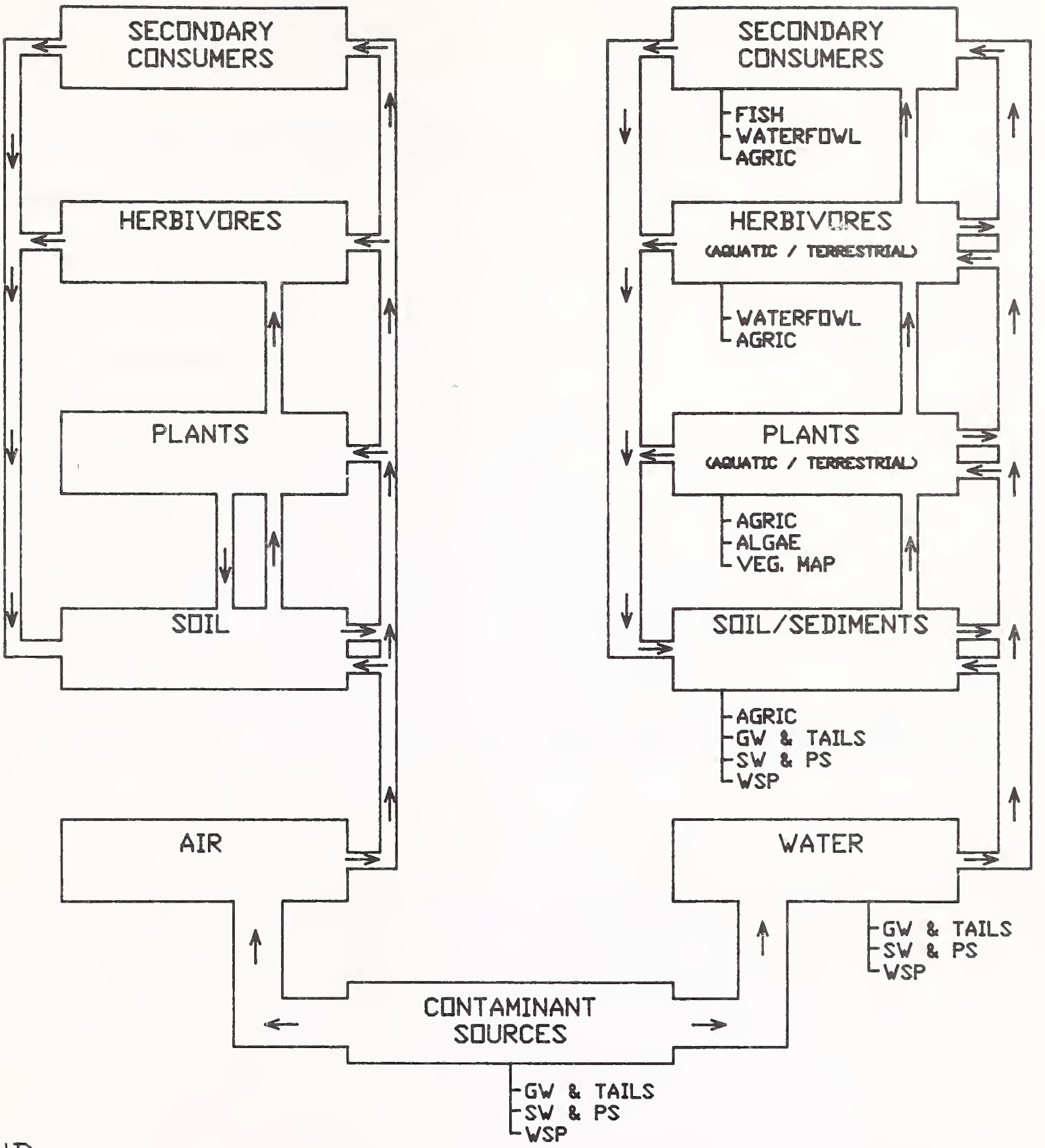
Data on contaminant sources are needed to identify remedial actions to reduce or remove contaminants. Data on contaminant pathways are needed to identify remedial actions that will reduce, remove, or divert contaminants so they do not continue to migrate from the sources(s). Data on contaminant fate are needed to assess the environmental and human health consequences of contaminant migration.

A simplified contaminant movement model is presented in Figure 1-2 that illustrates the source-pathway-fate concept as investigated by the SBC RI. This model does not show rates or amounts but is shown only to illustrate the source-pathway-fate concept. The model shows that certain compartments can be both pathways leading to other receptors (fates) and be receptors (receiving and retaining contaminants).

As illustrated by the model, the SBC RI did not investigate the air pathway of exposure to SBC contaminants directly. However, because of the proximity of the site to the Anaconda Smelter CERCLA site (which is a major air emissions source of elements identified as contaminants to Silver Bow Creek), air emissions of these contaminants were addressed in each investigation as appropriate to separate the air pathway from the water pathway.

The data developed during this first phase are adequate to begin the Feasibility Study portion of the RI/FS process. However, the results of the remedial investigations identified data gaps and the Feasibility Study may identify additional data gaps. These data gaps will be filled by a second phase of remedial investigation activities. This iterative process will continue until the selection of engineering alternatives for contaminant reduction or elimination is completed.

The work performed during this first-phase RI was guided by the documents prepared during the RI planning phase in 1984. At that



LEGEND:

- FISH =FISH TISSUE INVESTIGATION
- WATERFOWL = WATERFOWL INVESTIGATION
- AGRIC = AGRICULTURAL INVESTIGATION
- ALGAE = ALGAE INVESTIGATION
- GW & TAILS = GROUND WATER AND TAILINGS INVESTIGATION
- SW & PS = SURFACE WATER AND POINT SOURCE INVESTIGATION
- VEG MAP = RIPARIAN VEGETATION MAPPING
- WSP = WARM SPRINGS PONDS INVESTIGATION

FIGURE 1-2

SILVER BOW CREEK CONTAMINANT MOVEMENT MODEL

time, the Work Plan was composed as a compromise between available financial resources and the identified data gaps. The limited financial resources available required the phased approach so that extraneous data were not collected. Many proposed investigation tasks were deferred until the new data verified the need for additional work. One factor that affected the implemented scope of work was the evolving guidance from the USEPA on the requirements of an RI (for example, the guidance document from EPA for RI's was released in May of 1985, approximately a year after the RI planning was completed). Additionally, data developed during this first-phase RI has lead to the expansion of the SBC site, both upstream and downstream. These areas will be studied during the Phase II RI work.

To facilitate RI data collection and reporting, efforts were separated into ten individual investigations based on media and the source-pathway-receptor models:

- Surface Water and Point Source;
- Ground Water and Tailings;
- Warm Springs Ponds;
- Algae;
- Riparian Vegetation;
- Agriculture;
- Macroinvertebrate;
- Bioassay
- Fish Tissue; and
- Waterfowl.

In addition, a Quality Assurance/Quality Control Program and a Health and Safety Program governed all field and laboratory activities of the SBC RI. These two programs are discussed below.

1.1.1.1 Quality Assurance/Quality Control (Appendix F)

Data developed by the SBC RI will be used to evaluate human and environmental risk from the contaminants and to identify potential remedial actions. To ensure that the data developed during the SBC RI met the legal and scientific requirements for RI data, a Quality Assurance Plan (QA Plan) (MultiTech and Stiller and Associates 1984c) was prepared during the planning phases to guide the acquisition of SBC RI data.

The SBC RI QA Plan provides in specific terms the policies, organization, objectives, functional activities, and specific quality assurance (QA) and quality control (QC) objectives and activities necessary to meet the goals of the project. Although frequently used interchangeably, the terms quality assurance and quality control refer to two different concepts. Quality assurance is the "system for ensuring that all information, data, and resulting decisions compiled under a specific task are technically sound, statistically valid, and properly documented" (USEPA 1982). Quality control is the "mechanism through which quality assurance achieves it goals" (USEPA 1982).

MultiTech prepared the SBC RI QA Plan from January to July of 1984 under contract to the MDHES. Guidance from the USEPA available at that time was Interim Guidelines and Specifications For Preparing Quality Assurance Project Plans (USEPA 1980a). MultiTech received a draft copy of Evaluation Criteria for Existing Data From CERCLA Study Areas (USEPA, No Date) on June 13, 1984, and a final draft of that document on February 5, 1985 (USEPA 1985a). The SBC RI QA Plan was prepared without the aid of these evaluation criteria; however, the QA/QC requirements outlined by the SBC RI QA Plan and implemented during the SBC RI met the criteria. USEPA's guidance document on developing Data Quality Objectives (DQO's) was not available until after the SBC RI planning and field work were completed.

Preliminary review comments on the draft QA Plan were received from the USEPA Regional and Quality Assurance Office on June 4, 1984, after the draft QA Plan had been revised by MultiTech responding to MDHES comments. The final SBC RI QA/QC Plan was delivered by MultiTech to MDHES on July 24, 1984. MultiTech was awarded the SBC RI contract in November 1984, and began work using the SBC RI QA Plan.

A revision of the SBC RI Plan was submitted by MultiTech to MDHES on February 19, 1985 for approval. This revised SBC RI QA/QC Plan was proposed to streamline documentation while maintaining essential elements, to address sampling and analysis techniques not foreseen during the initial drafting of the QA Plan, and to address the

USEPA's June comments. With the exception of method detection limit (MDL) goals, the revisions were approved for implementation by MDHES. The MDL goals were revised and approved separately.

Copies of the SBC RI QA Plan are located at MultiTech Offices in Butte, Montana and in the offices of the Solid and Hazardous Waste Bureau, MDHES, Helena, Montana. The SBC RI QA/QC Report (Appendix F) was prepared to meet these objectives:

- Distribute to SBC RI Report readers a summary of the SBC RI Quality Assurance Plan;
- Document that the data meet USEPA QA/QC criteria for RI data;
- Document the implementation of the QA Plan;
- Document the external QA/QC audit findings;
- Document and summarize QA/QC decisions; and
- Discuss SBC RI Data Quality objectives.

1.1.1.2 Health and Safety Program

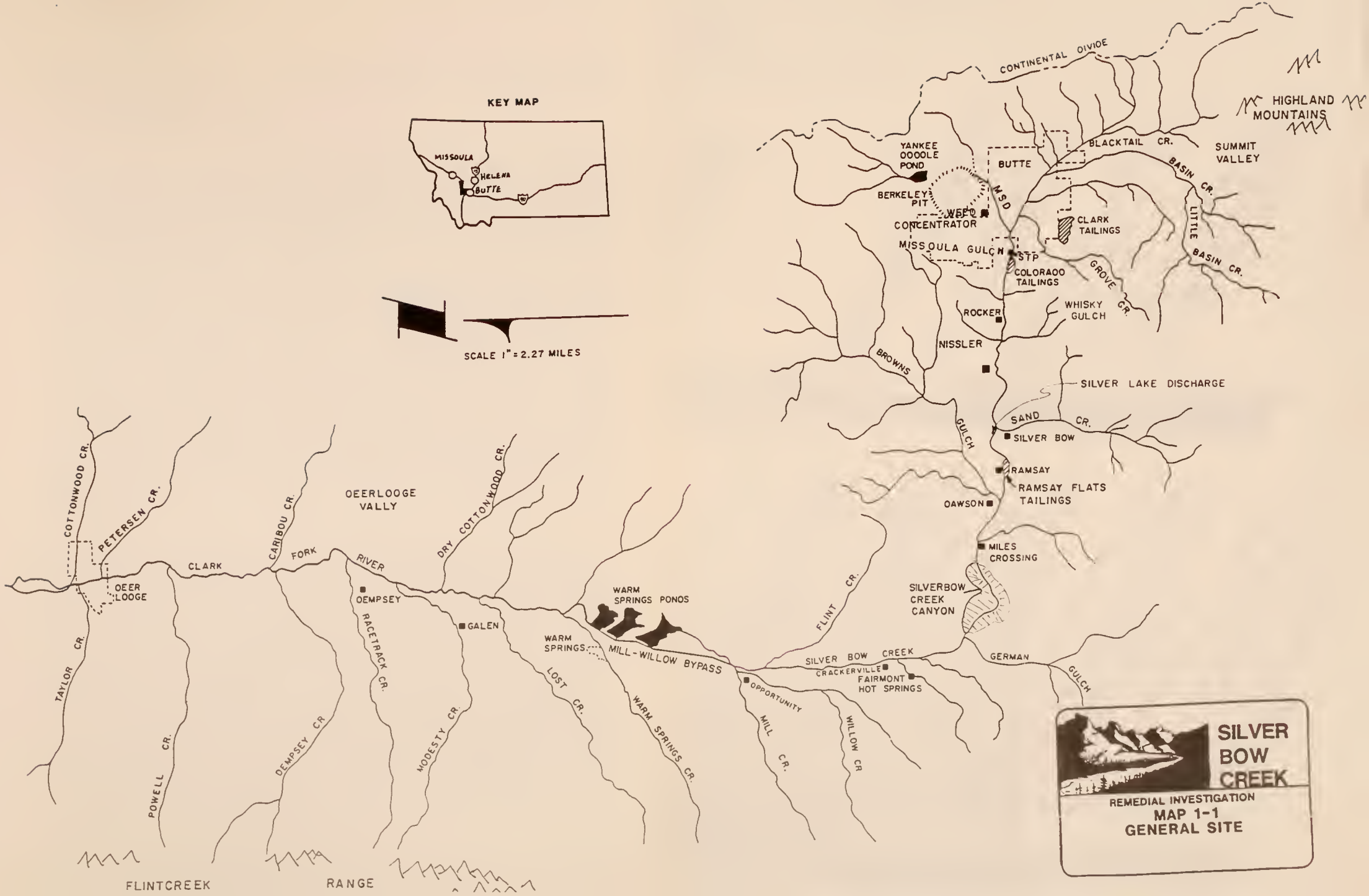
To protect the RI field and laboratory personnel, a Health and Safety Plan (MultiTech 1984) was prepared during the RI planning process. This plan identified pre- and post-investigation medical testing, protective clothing and devices, hazards, specific health and safety protective measures, and specific health and safety audits. This plan was adhered to during the SBC RI. Copies of the plan are available for review at MultiTech, 505 Centennial Avenue, Butte, Montana, and at the MDHES, Cogswell Building, Helena, Montana.

1.1.2 Summary Report

This SBC RI Summary report has been organized to review and integrate the findings of all SBC RI activities for use in the FS phase. Accompanying appendices report details of each investigation. The remainder of this chapter describes the site and its history. Chapter 2.0 is a Hazardous Substances Inventory of waste types, characteristics, and behavior found in Silver Bow Creek. The SBC RI Surface Water and Point Source Investigation is summarized in Chapter 3.0. Ground-water contaminant relationships are summarized in Chapter 4.0, based on the results of the SBC RI Ground Water Investigation. Chapter 5.0 summarizes the Warm Springs Ponds Investigation. Investigations summarized in Chapter 6.0 are all flora investigations (Algae, Riparian Vegetation, and Agriculture), while Chapter 7.0 discusses fauna investigations (Macroinvertebrate, Bioassay, Fish Tissue, and Waterfowl). A description of the Nature and Extent of Problems in the SBC site is found in Chapter 8.0. References cited are listed in the Reference Section.

1.2 SITE DESCRIPTION

Silver Bow Creek drains the northern portion of the Summit Valley, in southwestern Montana. The creek is located west of the Continental Divide, near the city of Butte. The area is part of the Northern Rocky Mountain physiographic province, and Map 1-1 shows major geographic features in the study area. A distinct change in the orientation of valleys in the study area is evident: the Summit


KEY MAP
MISSOULA
HELENA
BUTTE
SCALE 1" = 2.27 MILES
CONTINENTAL DIVIDE
HIGHLAND MOUNTAINS
YANKEE DOODLE POND
BUTTE
BLACKTAIL CR.
SUMMIT VALLEY
BERKELEY PIT
MSD
WSD
CONCENTRATOR
CLARK TAILINGS
BASIN CR.
LITTLE BASIN CR.
MISSOULA GULCH
STP
COLORADO TAILINGS
GROVE CR.
WHISKY GULCH
ROCKER
NISSLER
BROWNS GULCH
SILVER LAKE DISCHARGE
SAND CR.
SILVER BOW
RAMSAY
RAMSAY FLATS TAILINGS
DAWSON
MILES CROSSING
SILVERBOW CREEK CANYON
FLINT CR.
GERMAN GULCH
SILVER BOW CREEK
CRACKERVILLE
FAIRMONT HOT SPRINGS
OPPORTUNITY
MILL CR.
WILLOW CR
WARM SPRINGS CR.
LOST CR.
MILL-WILLOW BYPASS
WARM SPRINGS
WARM SPRINGS PONDS
GALEN
OEMPSEY
RACETRACK CR.
MODESTY CR.
DEMPSEY CR
POWELL CR.
TAYLOR CR.
OEER LODGE
CLARK FORK RIVER
CARIBOU CR.
OEERLOOGE VALLY
DRY COTTONWOOD CR.
PETERSEN CR.
COTTONWOOD CR.
FLINTCREEK RANGE
SILVER BOW CREEK
REMEDIAL INVESTIGATION
MAP 1-1
GENERAL SITE

Valley trends generally east to west, whereas the Deer Lodge Valley is oriented north to south.

The RI Study area was extended beyond the original CERCLA site boundaries to evaluate offsite impacts. The RI study area began at the outfall from the Weed Concentrator in Butte and extended to the Kohrs Bridge, North of Deer Lodge, Montana and included the Butte Metro Storm Drain (MSD), Silver Bow Creek, and the upper Clark Fork River (Map 1-1). This system drains a total of 1,005 square miles, as measured at Deer Lodge (U.S. Geological Survey 1983). The Summit and Deer Lodge Valleys range from approximately 0.25 miles to over 4 miles wide and are bordered by the Continental Divide, the Highland Mountains, the Anaconda Pintlar Range, and the Flint Creek Range. The valleys are primarily filled with Tertiary sediments, predominantly overlain by recently deposited (Quaternary) alluvium.

The study area contains several population centers; the largest is the city of Butte and the second largest is Deer Lodge. Numerous small communities are situated along Silver Bow Creek and the upper Clark Fork River, including Rocker, Nissler, Silver Bow, Ramsay, Crackerville, Opportunity, and Warm Springs (Map 1-1). Although none of these small communities have populations greater than 500 persons, in total they constitute a significant fraction of the study area's entire population. Numerous isolated rural residences are also present in the study area; they compose a relatively small percentage of the total population.

1.2.1 Geology

The geology of the Silver Bow Creek RI study area is diverse, with rocks ranging from Cretaceous intrusives to Quaternary alluvium. Rocks are largely siliceous, with zones containing valuable mineral deposits.

In the eastern portion of the study area, near Butte, the Boulder Batholith is composed primarily of highly mineralized quartz monzonite. The Butte Mining District has produced gold, silver, and copper, and lesser quantities of cadmium, bismuth, arsenic, selenium, and tellurium, from this deposit (Miller 1973).

The Deer Lodge Valley and the upper Clark Fork River are bounded on the west by the Anaconda-Pintlar and Flint Creek mountain ranges, both of which contain significant amounts of limestone. This lithologic difference from the Summit Valley is reflected in both soil character and surface- and ground-water chemistry. The alkaline nature of these materials encourages precipitation and removal of metals from solutions which come in contact with them.

Tailings, waste rock, and smelter wastes are present at locations throughout the study area. These materials generally overlie natural colluvium and fractured (or occasionally undisturbed) bedrock.

1.2.2 Soils

A diversity of soil types are present in the RI study area. Soils in the basins are developed primarily on upland slopes under coniferous forests and on valley fill sediments under grassland vegetation. Moderately deep soils have developed on alluvial fans and pediments (U.S. Soil Conservation Service 1973). In the valleys, gently sloping, deep soils have developed along terraces. Adjacent to Silver Bow Creek and the Clark Fork River, shallow, gravel-textured to deep, fine-grained alluvial soils have developed. Nutrient rich, organic soils of various depths are present in some low or wetland areas.

Much of the natural soil in the study area has been affected by mining wastes. Natural soils have been disturbed in the Butte area where mill tailings, smelter wastes, and mine waste rock are present. Many soils along Silver Bow Creek and the Clark Fork River floodplain are covered with waste materials which may contain a seasonally fluctuating water table.

These mining-related wastes are generally sandy textured, reflecting their granitic origin, and typically have high concentrations of metals and sulfide minerals. The oxidation of sulfide minerals produces acidic conditions that increase the solubility of many metals. Accumulation of bio-available heavy metals severely limits vegetation establishment, which limits soil development.

1.2.3 Climate

The SBC RI study area has a continental climate, characterized by short, cool, dry summers and cold winters. Average mid-winter temperatures are well below freezing, and mid-summer temperatures average between 60 and 65°F. Annual precipitation in Butte varies from 6 to 20 inches and averages approximately 11.5 inches. Annual precipitation patterns in the upper Clark Fork River valley are similar to those in Butte; an average annual precipitation of 13.2 inches has been measured in Anaconda. Generally, 50% of the annual precipitation in the Butte-Anaconda area falls in late spring and early summer.

Climate in the higher mountain elevations surrounding the study area is alpine to subalpine. This climate is characterized by colder temperatures and heavier precipitation, often in the form of snow. Melting of the mountain snowpack in spring and early summer provides the majority of the surface-water supply within the study area.

Streams in the area become ice-covered to partially ice-covered during the winter months. The area occasionally experiences warm Chinook (descending) winds which cause mid-winter thaws and subsequent high streamflows. Snow cover in the lower valleys usually melts in March to early April, with the mountain snowpack normally remaining through May and into June.

1.2.4 Hydrology

Silver Bow Creek and the upper Clark Fork River are sustained by a combination of natural and man-made features. In addition to precipitation, several ground-water inputs contribute to the surface flow at various points along the stream course. During low-flow periods, these inputs constitute a significant percentage of the flow.

1.2.4.1 Silver Bow Creek

Silver Bow Creek begins at the confluence of the Butte Metro Storm Drain (MSD) and Blacktail Creek, as shown on Map 1-1. The MSD is an open channel that was constructed in the early 1930s under the Works Progress Administration Program. This project consisted of realigning and filling the original Silver Bow Creek drainage, a lowland swampy area with numerous mine waste ponds along its upper reach. The MSD has little or no flow except in the event of periodic storm runoff, snowmelt episodes, or discharge from the Weed Concentrator.

Blacktail Creek originates in the Highland Mountains about 15 miles south of its confluence with the MSD, and it drains approximately 75 square miles. Basin Creek, a tributary, merges with Blacktail Creek approximately 2 miles before Blacktail flows into Silver Bow Creek.

Silver Bow Creek flows west out of Summit Valley through a constricted bedrock valley between Nissler and Silver Bow. This constriction caused natural aggradation in the lower portions of the valley. Early settlers report the floodplain was swampy and peaty before any changes of consequence were made by man (Meinzer 1914).

About 12 miles west of the MSD-Blacktail Creek confluence, Silver Bow Creek enters a canyon near Miles Crossing, shown on Map 1-1. Within this canyon Silver Bow Creek swings northward and flows for another 10 miles, terminating in the Warm Springs Ponds system.

The Butte Sewage Treatment Plant (STP) discharges into Silver Bow Creek on the western edge of the City of Butte. Minor ephemeral tributaries discharging into Silver Bow Creek in its upper reaches include Missoula Gulch, Whiskey Gulch, Gimlet Gulch, and Sand Creek. Perennial discharges to Silver Bow Creek include Browns Gulch and German Gulch. During the RI period, the water line from Silver Lake (west of Anaconda) to Butte discharged to Silver Bow Creek.

Silver Bow Creek flows through two major mining and milling waste deposits: the Colorado Tailings, located near Butte; and a large waste flat located near Ramsay. In addition, waste deposits of varying thicknesses are present along the entire course of Silver Bow Creek.

1.2.4.2 Warm Springs Ponds

East of Warm Springs, Silver Bow Creek flows into an impoundment facility operated by the Anaconda Minerals Company for the treatment of Silver Bow Creek water. This treatment facility consists of a series of three ponds, known as the Warm Springs Ponds. Water from Silver Bow Creek enters Pond 3 through a control structure. Water from Pond 3 is decanted by two towers into Pond 2. Water from Pond 2 is discharged to the Mill-Willow Bypass through a controlled spillway. Pond 1, located below Pond 2, collects seep water from Pond 2. The seep water then is pumped back to Pond 2 (See Map 1-1).

Operation of this facility consists of controlling water levels and flow rates through the ponds, and adding lime as necessary to control the pH of the discharge. The discharge from the ponds is permitted by the MDHES through the Montana Pollution Discharge Elimination System (MPDES) regulations.

1.2.4.3 Clark Fork River

The outfall from the Warm Springs Ponds system joins the Mill and Willow Creeks Bypass (which diverts Mill and Willow creeks around the Warm Springs Ponds system) and Warm Springs Creek to form the Clark Fork River. The Clark Fork River from Warm Springs to the end of the study area at the Kohrs Bridge, north of Deer Lodge, is a meandering, slightly braided stream located in a broad river valley.

The Clark Fork River has no major tributaries until the Little Blackfoot enters just south of Garrison, Montana; however, numerous smaller tributaries drain into the Clark Fork River between Warm Springs and Deer Lodge, Montana. These are shown on Map 1-1.

1.2.5 Flora

1.2.5.1 Algae

Algae community species composition in Silver Bow Creek reflects the concentrations of contaminants found in the system. Barry (1956), Janik and Melacon (1982), Bahls (1983), and the SBC RI Algae Investigation (Appendix D, Part 1) indicate Silver Bow Creek algae communities have been severely impacted by contaminant levels. Diversity of species is reduced, with metals-tolerant species dominating. Silver Bow Creek also carries high nutrient levels from sewer system input, which contribute to increased algae biomass, even though the diversity is low. Algae may play a role in metals transport in the Silver Bow Creek/Warm Springs Ponds/Upper Clark Fork River system.

1.2.5.2 Terrestrial Flora

In the floodplain vegetation associated with the tributary streams of Silver Bow Creek, the major overstory species include cottonwood, willow, and alder. Other species occuring include reedgrass, manna grass, and tall wheatgrass, with rush and cattails found where the

water table is at or above the ground surface. The plant communities associated with these tributary streams have not been affected by major industrial activity; however, the vegetation growing in the floodplains has been altered by man's activites, primarily suburban and urban development and agriculture. The tributary streams do not represent pristine conditions, but are representative of the possible beneficial uses of local floodplains.

Plant communities associated with Silver Bow Creek have been extensively affected by past urban and industrial activity. Inspection of the floodplain indicates the major impact to plant communities has been caused by deposition of metal-enriched waste materials covering the original floodplain. These areas are devoid of plant life, or if it exists, it is a sparse, weedy community of inland salt grass and the scorpion plant. Where the wastes have eroded away (exposing original alluvial soil) willows, tufted hairgrass, and bentgrass have recolonized.

Floral species found in the Warm Springs Ponds area represent wetland and upland communities. Vigorous wetland communities are growing on metal-enriched wastes, precipitates, and sediments which are continuously inundated. However, in areas not constantly covered with water, vegetation is similar to that found on the dry wastes as described above. Upland sites are representative of southwest Montana soil climax communities.

The Clark Fork River floodplain vegetation below the Warm Springs Ponds has not been affected by waste deposits as much as Silver Bow Creek. The climax plant community for the Clark Fork floodplain from Warm Springs to the confluence with the Little Blackfoot River alternates between a saline lowland range site and a silty range site with 10-14 inches precipitation (Ross and Hunter 1976). Both sites are characterized by grasses and short shrubs.

In many areas of the Deer Lodge Valley below the Warm Springs Ponds, the floodplain vegetation has been altered by agricultural practices such as the introduction of non-native species, cropping (mostly for hay), and grazing. Metal-enriched waste deposits also have affected the floral communities in this section of the study area. The wastes are found at bends in the river due to fluvial deposition and show the same limited floral communities exhibited by upstream waste deposits.

1.2.6 Fauna

1.2.6.1 Aquatic Insects

No record exists of Silver Bow Creek's biological conditions prior to the commencement of silver mining in Summit Valley in the 1860s.

No aquatic insects (macroinvertebrates) were reported for Silver Bow Creek by the USEPA or by the Montana College of Mineral Science and Technology in 1972 and 1973 (Fox 1972; Gless 1973). However,

Gless (1973) reported aquatic insects in Blacktail Creek and Yankee Doodle Creek above the Yankee Doodle Pond. Harner-White Ecological Consultants, Inc. (1982) reported Dipteran aquatic insects downstream of the Montana Street bridge in Butte and upstream of Rocker and found Trichopteran aquatic insects at Miles Crossing downstream of Ramsay and in large numbers at Gregson Bridge near Gregson Hot Springs. Mayflies were found the full length of Silver Bow Creek Stations in 1982 by Chadwick and Associates (1983).

Available recent data (Chadwick and Associates 1984) indicate an almost complete recovery of macroinvertebrates below the Warm Springs Ponds. While aquatic macroinvertebrate densities and diversities have improved below the ponds, they are unlikely to ever be as high as the lower Clark Fork River. This is probably because of Butte municipal sewage water enrichment (Chadwick and Associates 1983).

All data indicate that aquatic insects are recolonizing Silver Bow Creek, but that the system is still stressed by contaminants.

1.2.6.2 Fisheries

The tributaries of Silver Bow Creek have not been systematically inventoried for their fisheries (MDFWP 1980; Holton 1983; Munther 1983; and Walsh 1983). However, Basin Creek is known to have at least a marginal fishery of brook trout (Konizeski 1978) and Blacktail Creek contains some brook trout.

Silver Bow Creek from Butte to Warm Springs has no viable fishery. Willow Creek and Mill Creek, tributaries to the upper Clark Fork River in the vicinity of the Warm Springs Ponds, have moderate and substantial fisheries resources, respectively (MDFWP 1980).

The Warm Springs Ponds and the upper Clark Fork River both have viable fisheries, mostly brown trout (Hadley 1984). The upper Clark Fork River from the Warm Springs Ponds to Bearmouth, west of Drummond, is classified as a high priority fishery resource by the Montana Department of Fish, Wildlife and Parks (MDFWP 1980). However, in spite of this classification, the fishery in the upper Clark Fork River appears to have less than expected recruitment due to contamination of the aquatic system (Phillips 1983).

1.2.6.3 Terrestrial Fauna

The faunal communities occurring in the Summit Valley are common within the Northern Rocky Mountains. Outside urban and suburban areas of the valley, wild animals are frequently encountered. However, the main area of concern for the Silver Bow Creek Superfund site lies within the floodplain, and only those animals found there are considered in the following discussion.

Waterfowl are the major wildlife resource associated with the floodplains of tributary Blacktail Creek and Basin Creek. Waterfowl use streams in the spring and fall during migration, and several valley areas are used for nesting and brood rearing. The major areas used

for nesting include a wetland at the confluence of Blacktail Creek and Basin Creek and a small reservoir located on an ephemeral tributary to Blacktail Creek.

From the confluence of MSD with Blacktail Creek to the Warm Springs Ponds, Silver Bow Creek supports occasional use by waterfowl during the spring, summer, and fall. Other floodplain wild animals utilizing the creek in this section include deer and elk (in the canyon section of the creek), songbirds, small mammals, and upland game birds.

The Warm Springs Ponds are leased by the Montana Department of Fish, Wildlife and Parks (MDFWP) from the Anaconda Minerals Company (AMC) and are used as a Wildlife Management Area. Major emphasis of management for this area is waterfowl habitat enhancement. Waterfowl use the area heavily during the spring, summer, and fall, with some birds overwintering. The area is attractive to waterfowl due to its relatively shallow water, plants, fish (for fish-eating waterfowl), minor disturbance potential, and because of efforts by MDFWP to enhance waterfowl habitat through planting small grains, closing a portion of the area to hunting, and creating a nesting habitat through island construction. MDFWP developed some additional waterfowl production ponds north of the existing Warm Springs Ponds. These production ponds were constructed from gravel pits (excavated for interstate highway construction in the area) which filled with surface-water runoff and ground water. These ponds

added new waterfowl habitat to the Warm Springs/Clark Fork River area, which contributes to the overall attractiveness of the area to both waterfowl and hunters.

Waterfowl also are a major wildlife group occurring within the floodplain of the Clark Fork River that could be affected by contamination of the river. Waterfowl use the upper Clark Fork River year-round, with major migration peaks occurring in the fall and early spring. Duck and geese reproduction occurs in this section of river.

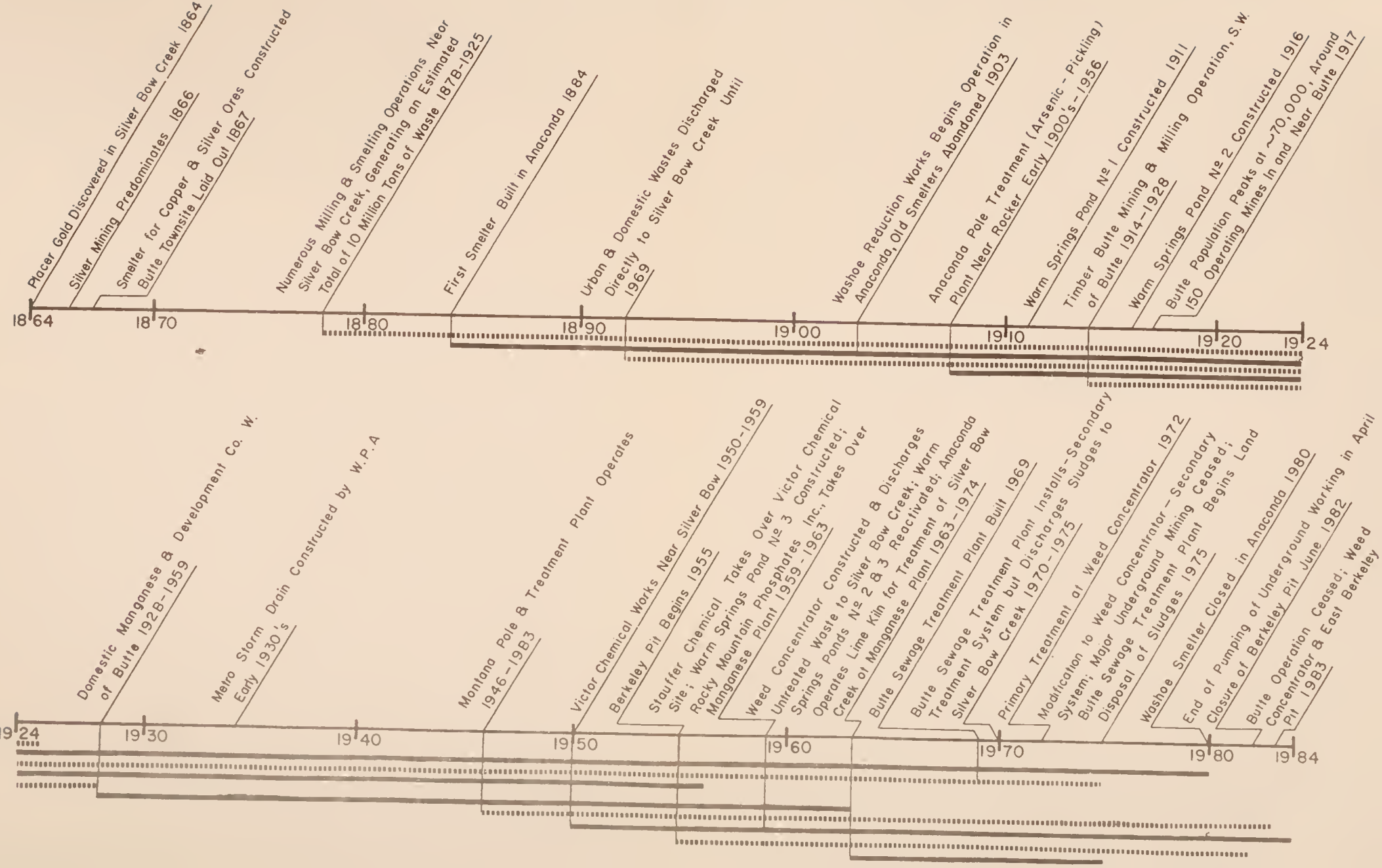
Only one threatened or endangered species occurs within the study area. The Northern Bald Eagle has been observed utilizing the Warm Springs Pond Area (Stoecker 1984). They are probably drawn to the area by the fall, winter, and spring concentrations of waterfowl, and no nesting in the area has been observed. Probable food sources for the eagles utilizing the area include waterfowl and fish.

1.3 MAN-MADE EFFECTS

The majority of man-made effects on Silver Bow Creek and the upper Clark Fork River were directly related to mining, milling, and smelting operations. Other influences on the natural environment are derived from population demands and industry. Figure 1-3 shows major historical events affecting the placement of wastes in the Silver Bow Creek floodplain.

FIGURE 1-3

HISTORIC CONTAMINATION OF SILVER BOW CREEK


Placer Gold Discovered in Silver Bow Creek 1864
Silver Mining Predominates 1866
Smelter for Copper & Silver Ores Constructed
Butte Townsite Laid Out 1867
Numerous Milling & Smelting Operations Near Silver Bow Creek, Generating an Estimated Total of 10 Million Tons of Waste 1878-1925
First Smelter Built in Anaconda 1884
Urban & Domestic Wastes Discharged Directly to Silver Bow Creek Until 1969
Washoe Reduction Works Begins Operation in Anaconda, Old Smelters Abandoned 1903
Anaconda Pole Treatment (Arsenic - Pickling) Plant Near Rocker Early 1900's-1956
Warm Springs Pond No. 1 Constructed 1911
Timber Butte Mining & Milling Operation, S.W. of Butte 1914-1928
Warm Springs Pond No. 2 Constructed 1916
Butte Population Peaks at ~70,000, Around 150 Operating Mines In and Near Butte 1917
1864
1870
1880
1890
1900
1910
1920
1924
Domestic Manganese & Development Co. W. of Butte 1928-1959
Metro Storm Drain Constructed by W.P.A Early 1930's
Montana Pole & Treatment Plant Operates 1946-1983
Victor Chemical Works Near Silver Bow 1950-1959
Berkeley Pit Begins 1955
Stauffer Chemical Takes Over Victor Chemical Site; Warm Springs Pond No. 3 Constructed; Rocky Mountain Phosphates Inc., Takes Over Manganese Plant 1959-1963
Weed Concentrator Constructed & Discharges Untreated Waste to Silver Bow Creek; Warm Springs Ponds No. 2 & 3 Reactivated; Anaconda Operates Lime Kiln for Treatment of Silver Bow Creek at Manganese Plant 1963-1974
Butte Sewage Treatment Plant Built 1969
Butte Sewage Treatment Plant Installs Secondary Treatment System but Discharges Sludges to Silver Bow Creek 1970-1975
Primary Treatment at Weed Concentrator 1972
Modification to Weed Concentrator - Secondary System; Major Underground Mining Ceased; Butte Sewage Treatment Plant Begins Land Disposal of Sludges 1975
Washoe Smelter Closed in Anaconda 1980
End of Pumping of Underground Working in April Closure of Berkeley Pit June 1982
Butte Operation Ceased; Weed Concentrator & East Berkeley Pit 1983
1924
1930
1940
1950
1960
1970
1980
1984

1.3.1 Early Placer Mining

The first record of any disturbance of the creek's natural channel was from 1864, when placer diggings began along Silver Bow Creek between the present towns of Silver Bow and Butte. The placer deposits found in the area were mostly of low-grade gold. During 1865-1866, placer mining operations spread to Missoula Gulch and Buffalo Gulch, up "The Hill" and to the north. The placer gold soon gave out, and most of the miners moved on by 1869, leaving behind a small contingent who continued mining. Placer mining in the channels of Silver Bow Creek and its tributary drainages undoubtedly caused increasing siltation of the creek and alteration of its natural channel; however, the activity probably had a relatively small overall impact on the water quality.

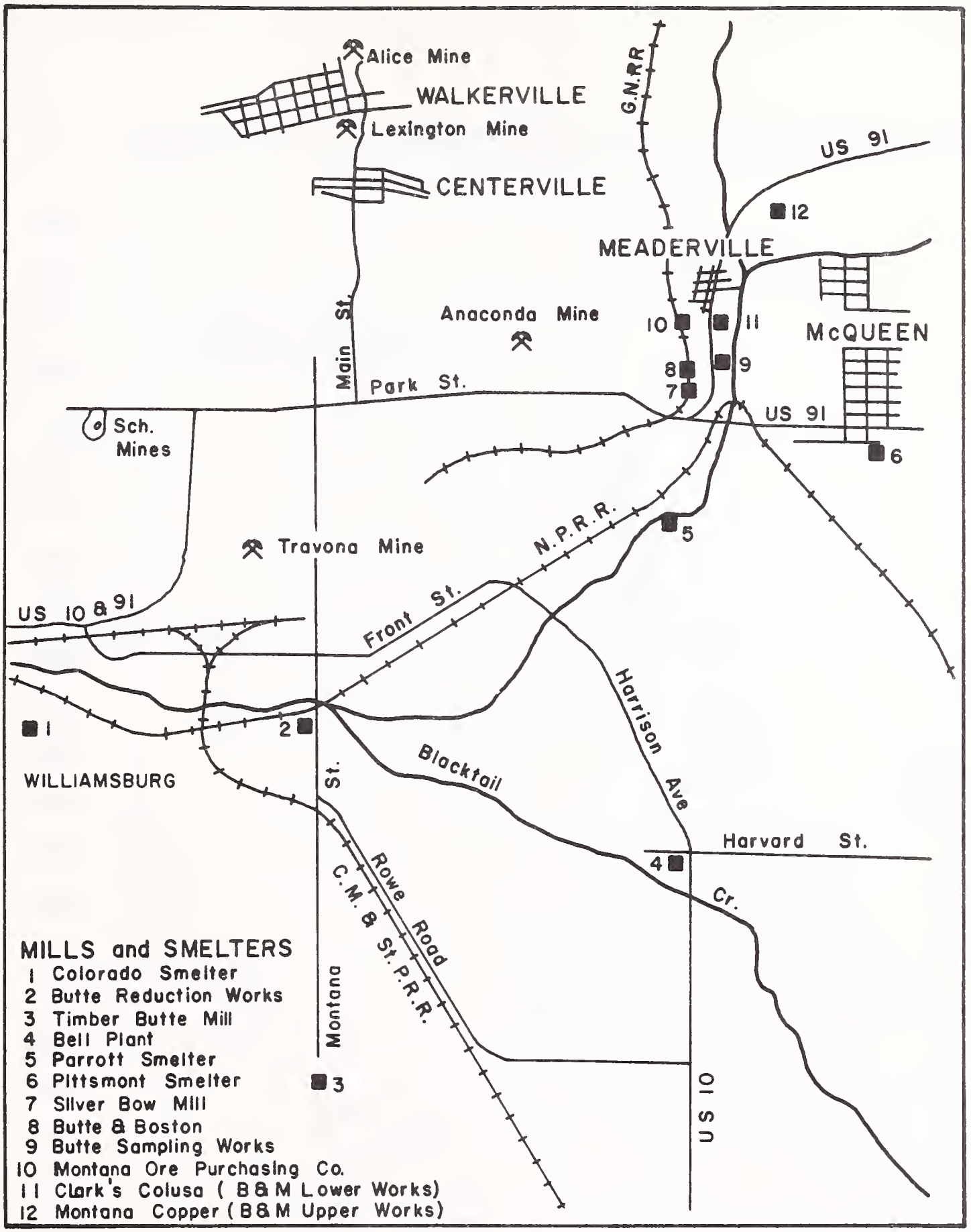
1.3.2 Underground Mining, Milling, and Smelting

In addition to the placer mining activity along Silver Bow Creek, some hard rock mining occurred on veins outcropping on the hills north of the creek. From 1866 to 1868, several small metal ore mills/smelters and a wet-process quartz mill (the Davis Mill) were built along Silver Bow Creek to process this ore (Smith 1952).

Although some copper and silver were produced by these smelters, all were shutdown by 1869, and little mining activity is recorded for the years 1869-1874 (Freeman 1900).

On January 1, 1875, William Farlin re-staked some claims on the hill (Travona Mine) as a result of high silver assays of some ore found in the area. This action rejuvenated mining activity and by 1878 several small milling/smelting operations were producing on "The Hill". From 1879-1885, at least six major smelters were built along Silver Bow Creek from Meaderville to Williamsburg (Map 1-2) (Historical Research Associates 1983; Meinzer 1914; Freeman 1900; Smith 1952). The smelters operated more or less continuously for 20-30 years until 1910 (Figure 1-4) (Historical Research Associates 1983).

Anaconda Copper Mining (ACM) completed a smelter in the new town of Anaconda in 1884, downstream from Butte about 27 miles. By 1910, Anaconda Copper Mining had purchased and closed all but one of the major concentrators/smelters in the Butte area, and most of the ore was being shipped to the Anaconda smelter for milling and processing. The only major smelter still in operation in the Butte area after 1910 was the Pittsmont, which operated until 1930. The Timber Butte Mill, which processed zinc ore largely from the Elm Orlu Mine (Smith 1952) was located south of Silver Bow Creek and operated until the mid-1930's. Tailings from the Timber Butte Mill, Butte and Superior, and East Butte concentrators were sluiced in various amounts to tributaries of Silver Bow Creek until at least 1918 (Flynn 1937).



Source: Smith 1953

SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 1-2

MILLS and SMELTERS of EARLY BUTTE

SMELTERS & FACTORIES ALONG SBC - TIME OF OPERATION

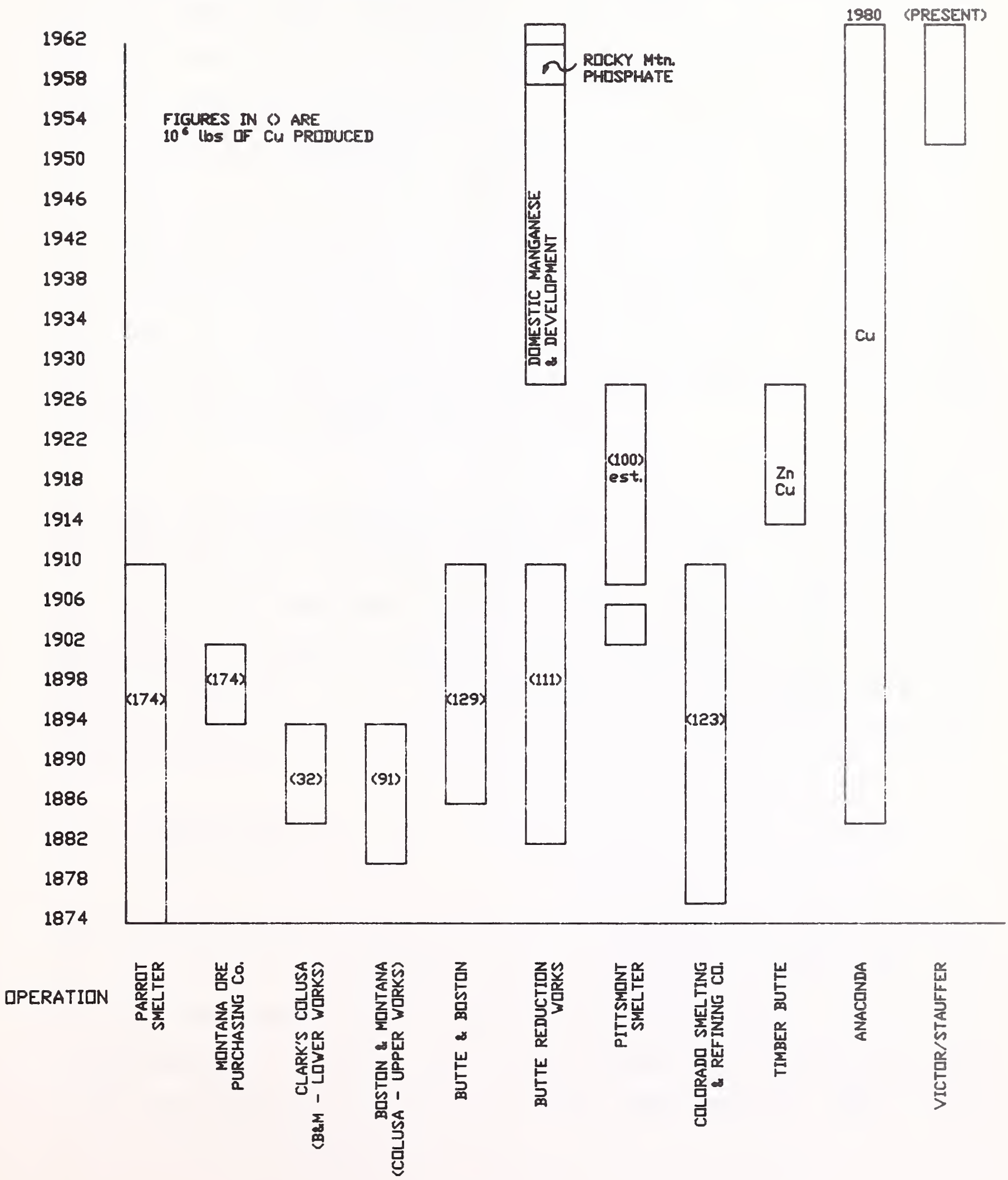


FIGURE 1-4

By 1917, nearly 150 mines operated in and near Butte. Over the next 60 years these underground mines either were purchased by Anaconda Copper Mining or ceased production. Anaconda Copper Mining began an open-pit copper mine in 1955, the Berkeley. The company built the Weed Concentrator in Butte, completing construction and starting operations in 1964. Most of the ore from the Berkeley Pit and operating underground mines then were milled and concentrated at the Weed Concentrator. Concentrates were shipped to the city of Anaconda for smelting. Anaconda Copper Mining has changed names several times, first becoming The Anaconda Company in 1955, then Anaconda Minerals Company (AMC) in 1977.

In 1976, all underground operations were closed by the company, but the Berkeley Pit continued production until 1982. All mining and milling by the Ananconda Minerals Company ceased in 1983 with the shut down of mining in the East Berkeley Extension Pit. In 1985, Montana Resources, Inc. purchased some of the Anaconda Minerals Company properties in Butte and resumed mining and milling in 1986.

1.3.3 Mitigation

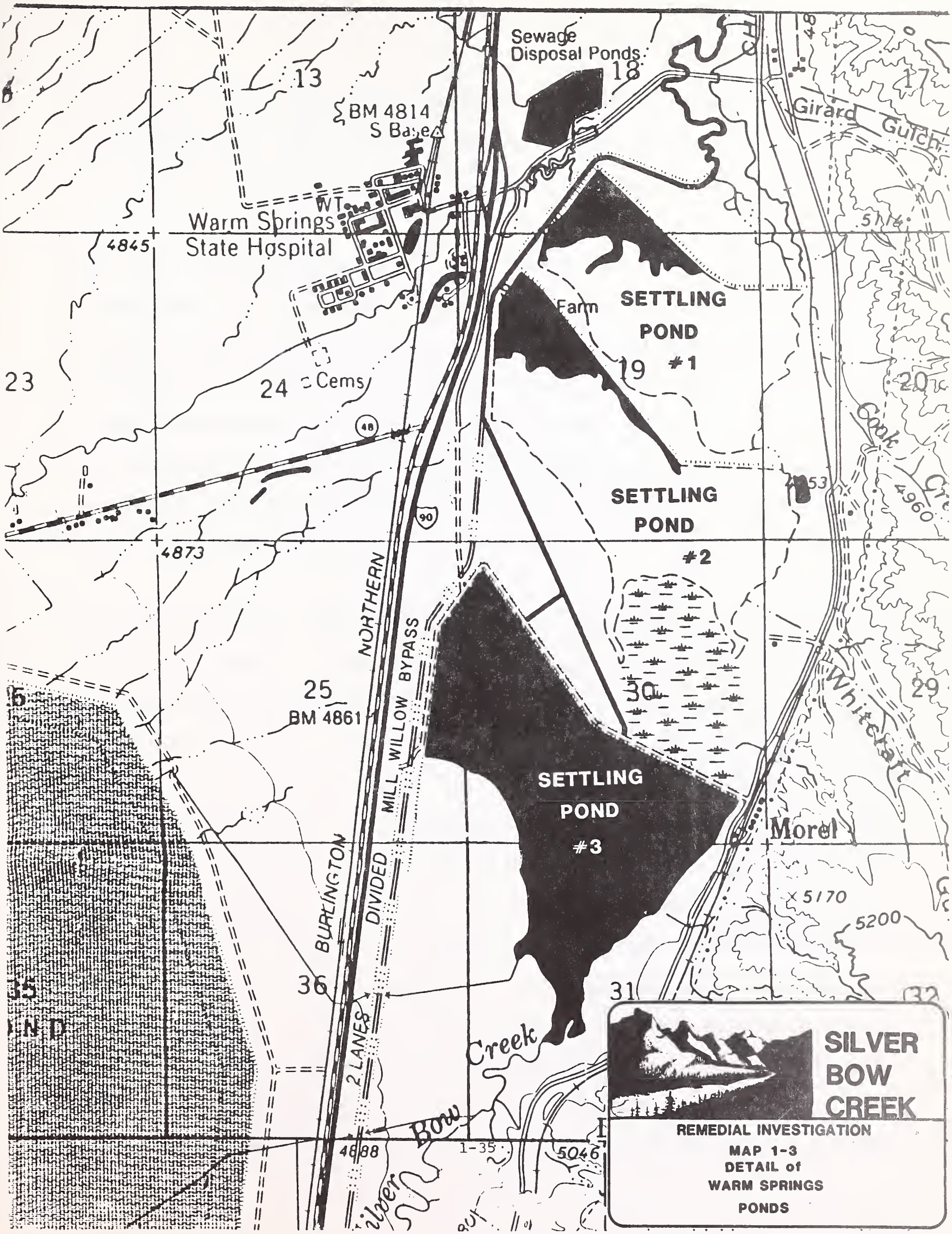
From the beginning of mineral concentration/smelting activity (1880 to 1911) metal-enriched waste materials from the Butte area were carried downstream to the Clark Fork River at least as far as Milltown Reservoir, built in 1907 (Moore 1985), and probably further (Weed 1912; Montana Historical Society 1986; Freeman 1900; Smith

1952; Flynn 1937; Noble 1911; James 1975). The distance between Butte and the Milltown Dam is 147 river miles.

A survey and map of the waste deposits along the Deer Lodge River (Silver Bow Creek) near its confluence with Warm Springs Creek was made in 1904 (F.C. Noble - probable author). The extent of these deposits are shown on this map, and descriptions of deposits are identified as being "heavy" in some areas. In 1910, F. C. Noble revised the map showing more recent waste deposits from the high water overflows of 1908 and 1910 (Montana Historical Society 1986).

Noble (1911) also describes a dike apparently built by the Henry Williams Ranch in the 1890's to protect ranch property from deposition of waste material. Other ranches in the Deer Lodge Valley also were affected by waste deposits, and some settlement of damages (tailings easements) may have been made by the Anaconda Copper Mining Company.

Attempts to control the amount of sediment being transported by Silver Bow Creek and to prevent the sediment from entering the Clark Fork River were made by the Anaconda Copper Mining Company first in 1918-1920. At this time, two dams were built across Silver Bow Creek near the town of Warm Springs, creating Warm Springs Ponds 1 and 2 (Map 1-3). The dam for Pond 1 was 20 feet high and the dam for Pond 2 was 18 feet high. These ponds on Silver Bow Creek were built to act as final settling basins and


Sewage
Disposal Ponds
13
18
17
BM 4814
S Base
Girard
Gulch
WT
Warm Springs
State Hospital
4845
5114
Farm
SETTLING
POND
#1
19
23
24
Cems
20
Cook
48
53
4960
SETTLING
POND
#2
4873
NORTHERN
MILL
WILLOW
BYPASS
90
25
BM 4861
30
29
Whitetail
SETTLING
POND
#3
Morel
5170
5200
BURLINGTON
DIVIDED
2 LANES
36
31
Creek
Bow
4888
I-35
5046
SILVER
BOW
CREEK
REMEDIAL INVESTIGATION
MAP 1-3
DETAIL of
WARM SPRINGS
PONDS

clarifiers for the Opportunity Tailings Pond overflows, other plant discharges from the Anaconda Smelter, and tailings in the Deer Lodge River (Silver Bow Creek) (Flynn 1937; Capron 1922).

By 1912, much aggradation of the Silver Bow Creek channel at its confluence with Blacktail Creek was noted by Meinzer (1914). Sediment deposition in valley lowland areas was facilitated by the obstruction of Silver Bow Creek by various slag dumps, bridges, and other structures along the creek channel (Meinzer 1914). As a consequence of the large amount of sediment deposited in the Silver Bow Creek channel, flooding was frequent along Silver Bow Creek and Blacktail Creek (GCM Services, Inc. 1983).

Periodic attempts were made to dredge the channel, but the large amount of material available upstream, combined with the restricted outlet, made dredging efforts futile (Silver Bow County Commissioners' Minutes 1933). Silver Bow Creek remained a dirty, foul-smelling stream until 1933-1937, when the channel in Butte and above Montana Street was excavated, straightened, and lined with granite and slag (smelting waste) blocks by the Federal Works Progress Administration (GCM Services, Inc. 1983). This greatly aided drainage of Silver Bow Creek and isolated the waste and sediment deposits from the erosive action of the creek. As a consequence of channelization, sediment supply to Silver Bow Creek above its confluence with Blacktail Creek probably was decreased. However, large quantities of sediment/wastes were still available from existing deposits along Silver Bow Creek below the channelized section and from waste

rock dumps in Butte. Channelization of the upper portions of Silver Bow Creek also increased the ability of the creek to erode downstream waste/sediment deposits by increasing flood flows and stream competence.

Historical photographs indicate sediment load conditions probably stabilized through the 1950's, with some wastes still being derived from areas of Silver Bow Creek above the WPA channelized section. Sediment from waste rock dumps, natural sediment, and flocculated constituents still were contributing loads to Silver Bow Creek throughout this time period.

In 1955, The Anaconda Company began operating the Berkeley Pit near Meaderville, a Butte neighborhood. This excavation, and the construction of the Weed Concentrator presently near the pit's south rim, greatly modified and removed much of the tailings deposits that were present in and near the upper Silver Bow Creek stream channel.

A third (and much larger) 28-foot-high dam upstream of Warm Springs Pond 2 was built by The Anaconda Company between 1954 and 1959, primarily for sediment control (Hydrometrics 1983b; Stephenson 1986). This created Warm Springs Pond 3. The height of this dam was increased to a total height of 33 feet in 1967-1969 (Hydrometrics 1983b), and the dam for Warm Springs Pond 2 was raised five feet to a total height of 23 feet during the same time period (Stephenson 1986). The area of the Warm Springs Ponds was covered

by The Anaconda Company's mining permit from the Montana Department of State Lands first issued in 1973. The discharge from the ponds was permitted by the Montana Department of Health and Environmental Sciences.

1.3.4 Other Waste Materials

Several other types of waste materials contributed to the degradation of Silver Bow Creek water quality, as indicated in the following discussion.

1.3.4.1 Waste-Water Discharges from Butte Mining Operations

The history of waste-water discharges into Silver Bow Creek begins with water pumped from mines in the Butte area. Beginning about 1876, the mines began encountering sufficient water that pumping was required for mining to continue. In 1912, the total pumping rate for all mines in the Butte area was between 4,000 and 5,000 gallons per minute (gpm) continuously (Meinzer 1914). Most of this water was eventually discharged into the creek. Additional waste-water discharges from the various milling/smelting operations along Silver Bow Creek is probable, although no records of these discharges remain.

Precipitation of copper from the water being pumped out of the mines was successfully achieved by William Ledford in 1901 (Smith 1952). From 1901 to 1955 the water was discharged directly into

Silver Bow Creek after copper precipitation. After 1955, dumps composed of low-grade ore from the Berkeley Pit mining operation were leached with the water pumped from the underground mines. Copper was precipitated from the leach solution, and the solution was discharged into the creek (CH_2M Hill 1983). The waste water from the precipitation process was discharged directly into Silver Bow Creek until 1972 (Spindler 1977).

With the start-up of the Weed Concentrator in 1964, a new discharge from the Butte Operations began. Ore processing increased, and by 1972 an average of 13 million gallons per day (MGD) of process water was being discharged into Silver Bow Creek from the Concentrator. Discharge into the creek from the Yankee Doodle tailings ponds was 6 MGD in 1972 (Spindler 1977). The quantity of water discharged by these sources at earlier dates is not known. Table 1-1 gives an example of the chemical characteristics of mine water and precipitation plant spent leach solution discharged into Silver Bow Creek in 1972.

In 1967 Warm Springs Pond 3 was converted by The Anaconda Company from a sedimentation facility into a treatment facility for mill losses, precipitation plant spent solution from the Butte Operations, and overflow from the Opportunity Ponds (Spindler 1977). Treatment consisted of introducing a lime/water suspension from the Anaconda Smelter into Silver Bow Creek above Warm Springs Pond 3. The addition of the lime suspension raised the pH of the creek water to facilitate precipitation of metals in the Warm Springs

TABLE 1-1
CHEMICAL CHARACTERISTICS OF MINE WATER AND PRECIPITATION PLANT SPENT LEACH SOLUTION DISCHARGED INTO SILVER BOW CREEK IN 1972
(September 16, 1972)

	Plant Precipitation	Mine Water
pH	2.13	2.01
	mg/L	mg/L
Fe	3450	701
Cu	76	186
Zn	570	170
Al	647	183
Ca	369	287
Mg	463	175
SO_4	13,370	4,966
SiO_2	340	90
Cl	40	29
Total Dissolved Solids	22,900	8,780

Source: Spindler 1977

Ponds. The pond system worked well, except that under certain weather and stream conditions, flocculated solids overflowed to the Clark Fork River (Spindler 1977).

By 1973, treatment of precipitation plant water was combined with "superlimed" tailings for dispersal into the tailings ponds. This improved the quality of water being discharged into Silver Bow Creek, as shown in Tables 1-2 and 1-3. Beginning in 1973, recycling of water in the concentrator reduced discharges from the Butte Operations to an average of 12 MGD (6 MGD of concentrator process water, and 6 MGD of tailings overflow water). In 1976 the treatment system at the Butte Operations was modified further, improving the quality of water being discharged into Silver Bow Creek (Table 1-4). Additional water conservation measures at the Butte Operations in 1976 decreased the quantity of water discharged into the creek to 9.5 MGD. The history of waste-water discharges from the Butte Operations is summarized in Table 1-5.

1.3.4.2 Butte Waste Water

Untreated domestic sewage from the city of Butte was discharged into Silver Bow Creek until 1970. Because of the severity of aggradation in the early 1900s, Silver Bow Creek did not transport all the sewage downstream, and much of it collected in nearby swamps (GCM 1983). In 1969, the Butte sewage treatment plant was built. In June 1970, a secondary treatment facility began operation, but the sludge recovered continued to be discharged into Silver Bow

TABLE 1-2
SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE METROPOLITAN STORM DRAIN RECEIVING BUTTE OPERATIONS EFFLUENTS AND SILVER BOW CREEK, OCTOBER 1, 1971 TO SEPTEMBER 30, 1972; OCTOBER 1, 1972 TO SEPTEMBER 30, 1973 AND DURING 1975.

	Metro Storm Drain 1/4 mi. below Butte Operations	
	Avg.	Max.
10/1/71 - 9/30/72		
pH	3.15**	4.86**
Turbidity (JTU)	1608	5000
TSS* (mg/l)	--	--
Fe "	796	2395
Cu "	70	285
Zn "	248	1250
10/1/71 -9/30/73		
pH	5.72**	12.78**
Turbidity (JTU)	75	550
TSS (mg/l)	132	1200
Fe "	7.43	88
Cu "	1.44	11.4
Zn "	2.07	26.0
1975		
pH	9.01**	11.87**
Turbidity (JTU)	16	40
TSS (mg/l)	27	82
Fe "	0.22	0.96
Cu "	0.1	0.24
Zn "	0.17	0.35

* Total Suspended Solids
** Minimum and maximum values given to show range of pH.

Source: Spindler 1977.

TABLE 1-3
SOME MONITORING RESULTS OF BUTTE OPERATIONS
WASTE WATER TREATMENT SYSTEM DURING 1974 AND 1975.

Parameters	Maximum Allowed By EPA	Tailing Pond Surplus		Number of Times Over Maximum*	Process Res. Overflow		Number of Times Over Maximum*	Sec. Treat. Dis.		Number of Times Over Maximum*
	mg/L	mg/L			mg/L			mg/L		
1974		Avg.	Max.		Avg.	Max.		Avg.	Max.	
TSS	50	12.8	286	6	43.5	220	56	-	-	-
Fe	2.0	0.48	4.4	8	0.36	9.0	6	-	-	-
Cu	1.0	0.1	1.0	0	0.22	3.0	11	-	-	-
Zn	1.0	0.45	4.5	21	0.16	1.6	2	-	-	-
Operating Time		62.5%			70.7%					
1975										
TSS	30	10.2	96	1	-	-	-	12.3	80	13
Fe	2.0	0.14	0.97	0	-	-	-	0.12	0.87	0
Cu	1.0	0.04	0.25	0	-	-	-	0.06	0.42	0
Zn	1.0	0.07	0.93	0	-	-	-	0.13	0.75	0
Operating Time		22.7%						95.6%		

* Discharge discontinued when characteristics approach regulatory standards.

Source: Spindler 1977.

TABLE 1-4
FLOW AND MASS LOADING OF SOME METALS IN
SILVER BOW CREEK
JULY 14, 1976

Station	Flow ft^3/sec	Iron		Copper		Zinc	
		mg/l	lb/day	mg/l	lb/day	mg/l	lb/day
Metro storm drain 1/2 mile below Butte Operations	13.6	0.23	17	0.28	20	0.42	31

Source: Spindler 1977.

TABLE 1-5
HISTORIC SUMMARY OF MINING RELATED
DISCHARGES TO SILVER BOW CREEK - BUTTE
OPERATIONS 1876 - 1983

Time Period[a]	Waste Type	Receptor	Discharge (MGD)
1876	Untreated Mine Water →	SBC[b]	Unknown
1902	Mine Water → ppt Cu[c] →	SBC	Unknown
1912	Mine Water → ppt Cu →	SBC	~5-6
1955	Mine Water → Leach Dumps → ppt Cu →	SBC	
1963-1972	(Untreated) Mine Water → Leach Dumps → ppt Cu →	SBC	6
	(Untreated) Mill Wastewater →	SBC	7
	(Untreated) Tailings Pond →	SBC	6
1972-1976	(Untreated) Mill Wastewater →	SBC	6
	(Treated) Tailings Pond →	SBC	6
1976	(Treated) Mill Wastewater →	SBC	6.5
	(Treated) Tailings Pond →	SBC	3

February 1983 - Discharge Ended

(a) Dates indicate known activity for that date, inclusive.
(b) SBC = Silver Bow Creek.
(c) ppt Cu = Copper Precipitation Plant.

Creek until 1975. At that time land disposal was initiated. Storm runoff from the mined lands around Butte and the urbanized area of uptown Butte is routed through open channels and underground piping to the Butte MSD.

1.3.4.3 Montana Pole and Treatment Plant

Additional possible historic discharge into Silver Bow Creek is from the Montana Pole and Treatment Plant located southwest of Butte. This plant operated from 1946 to 1982 (Arrigo 1983). Discharge effluents consisted of condensate from the pole treating process.

1.3.4.4 Anaconda Post Treatment Facility

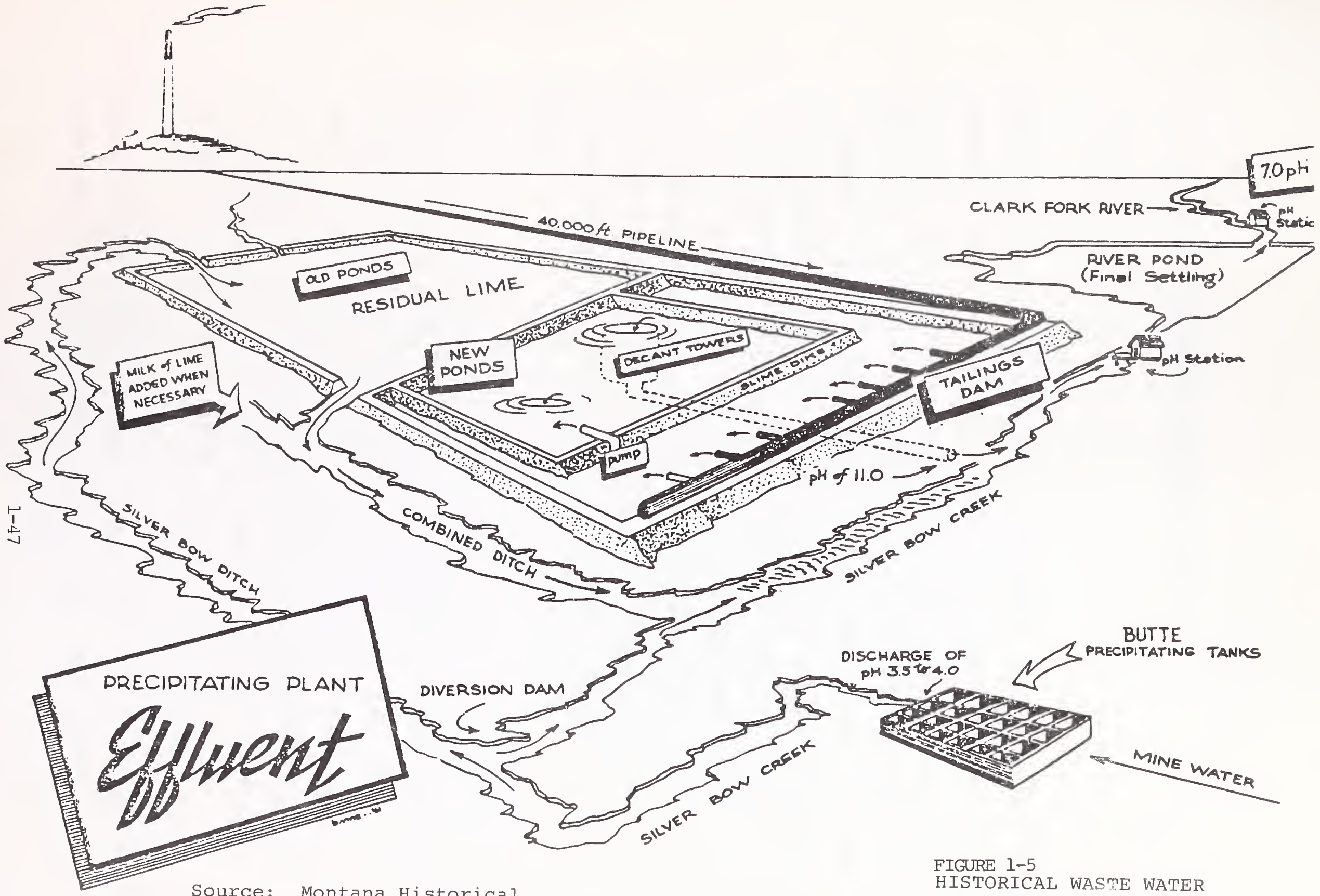
At the Anaconda Post Treatment Facility near Rocker (Pickling Plant), mine timbers were treated with a preservative containing arsenic. Waste material from the pressure treatment was dumped along the banks of Silver Bow Creek. This facility operated at Rocker from the early 1900's until 1956, when the treating operation was moved to the Anselmo Mine site (Central Timber Yard) in Butte. Also, creosote was used at this plant to treat poles and to lubricate the skids for mine timber loading and unloading.

1.3.4.5 Victor-Stauffer Chemical Plant

Untreated processing waste water originating from a chemical plant located near Ramsay was discharged into Silver Bow Creek until 1972. This plant had operated since 1950, producing elemental phosphorous. In 1972 steps were taken to provide a closed recycling system of processing waters. In 1975 the system was completed, and improvements were made in 1979 and 1982 which further reduced the risk of contaminant discharge into the creek (CH_2M Hill 1983).

1.3.4.6 Waste Water From Anaconda Smelter

Waste water from the Anaconda Smelter flowed into a series of ponds (Anaconda Ponds, Opportunity Ponds) from 1884 until 1980. These ponds settled out particulate matter from the waste water, and overflow from them entered Silver Bow Creek above the Warm Springs Ponds. Between 1937 and 1942 a dam near Gregson diverted the creek water to the older Opportunity Tailings Ponds. Flooding of these ponds kept dust and sand from blowing off the inactive areas. A flow sheet (Figure 1-5) prepared by the Anaconda Copper Mining Company (Montana Historical Society 1986) illustrates this system. Waste water from the town of Anaconda also was routed into various ponds in the Anaconda/Opportunity pond system and then overflowed into Silver Bow Creek.



Source: Montana Historical Society, 1986

FIGURE 1-5
HISTORICAL WASTE WATER
FROM ANACONDA SMELTER
1932-1947

1.3.5 Residual Effects of Disturbances

1.3.5.1 Tailings

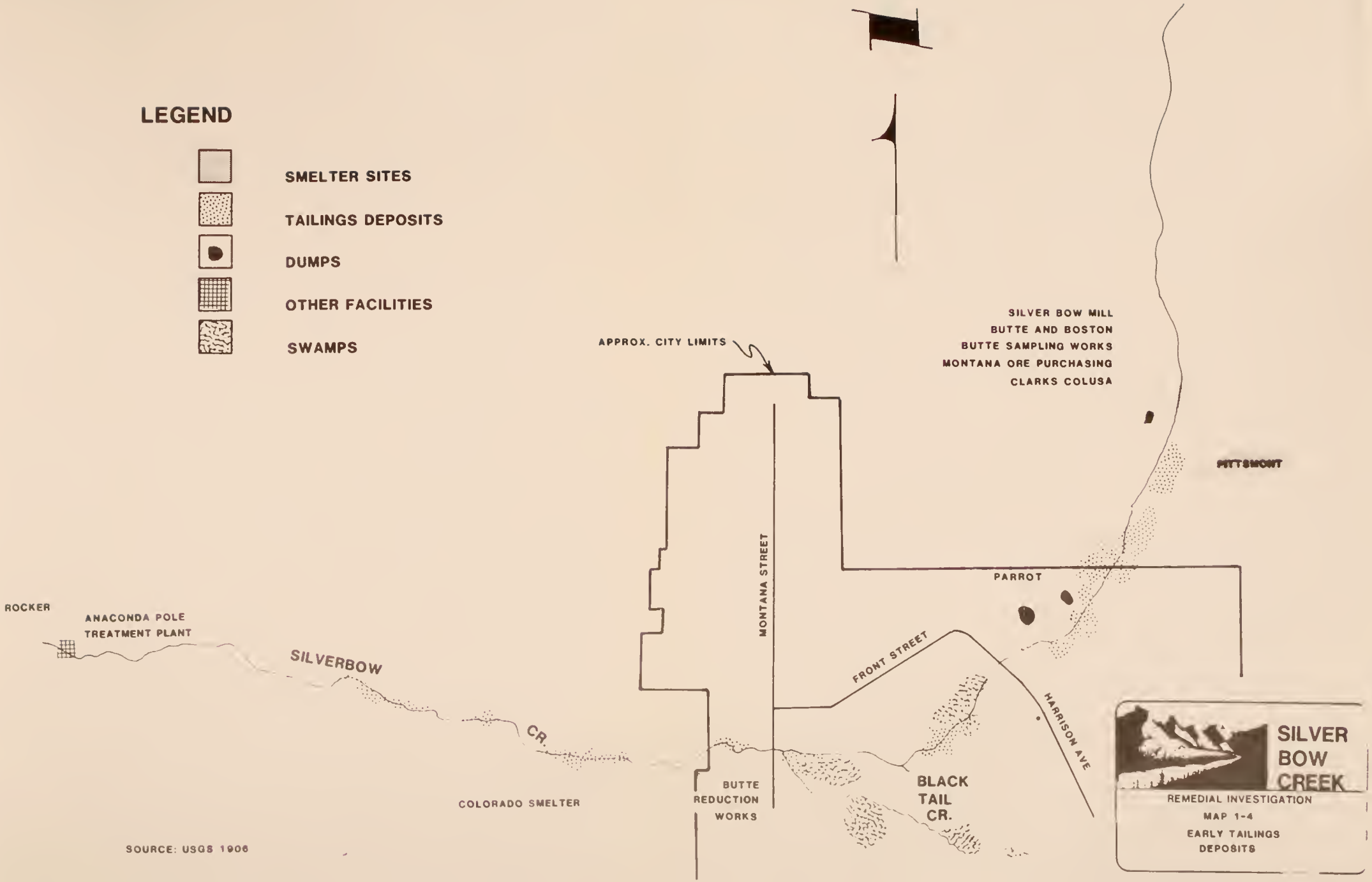
Studies of Silver Bow Creek and the Clark Fork River above Milltown Reservoir identified extensive metal-enriched sediment deposits on the banks and floodplains of Silver Bow Creek and the Clark Fork River (Moore 1985; Hydrometrics 1983a and 1983b; USEPA 1984; SBC RI Appendix B). Potential sources of the sediment included mill tailings, mine waste rock, natural sediment, and mine water precipitates. Tailings from Butte area smelters and the Anaconda Smelter are probable sources of the tailings component of the sediment along Silver Bow Creek and the Clark Fork River because of the locations of the mills and their practices of impounding tailings in the floodplains or discharging tailings directly into Silver Bow Creek.

Sampling studies performed on these deposits (Peckham 1979; Hydrometrics 1983d; Moore 1985; SBC RI, Appendix B) indicate that these sediments contained high levels of arsenic, copper, lead, zinc, and cadmium. The concentrations of metals found in these sediments were many times the background level found in other sediment along tributary drainages and in ancient lake bed sediment along the Clark Fork River (Moore 1985; SBC RI, Appendix B).

The uppermost sediment layer along the Clark Fork River (Moore 1985) and along Silver Bow Creek clearly lies above an older soil

surface which developed on natural floodplain sediments. The underground soil horizon contains vegetation partially buried by the metals-enriched sediment, indicating a very recent origin for the sediment. These recent sediments are orange and gray, very micaceous, fine-grained sand and mud, with green and blue copper sulfate and carbonates precipitating on exposed surfaces (Moore 1985; SBC RI Appendix B). The high metal concentrations, physical description, and evidence of recent sedimentation indicate that these sediments contain mill tailings, although variable quantities of mine waste rock, natural sediment, and flocculated constituents are incorporated into these materials also.

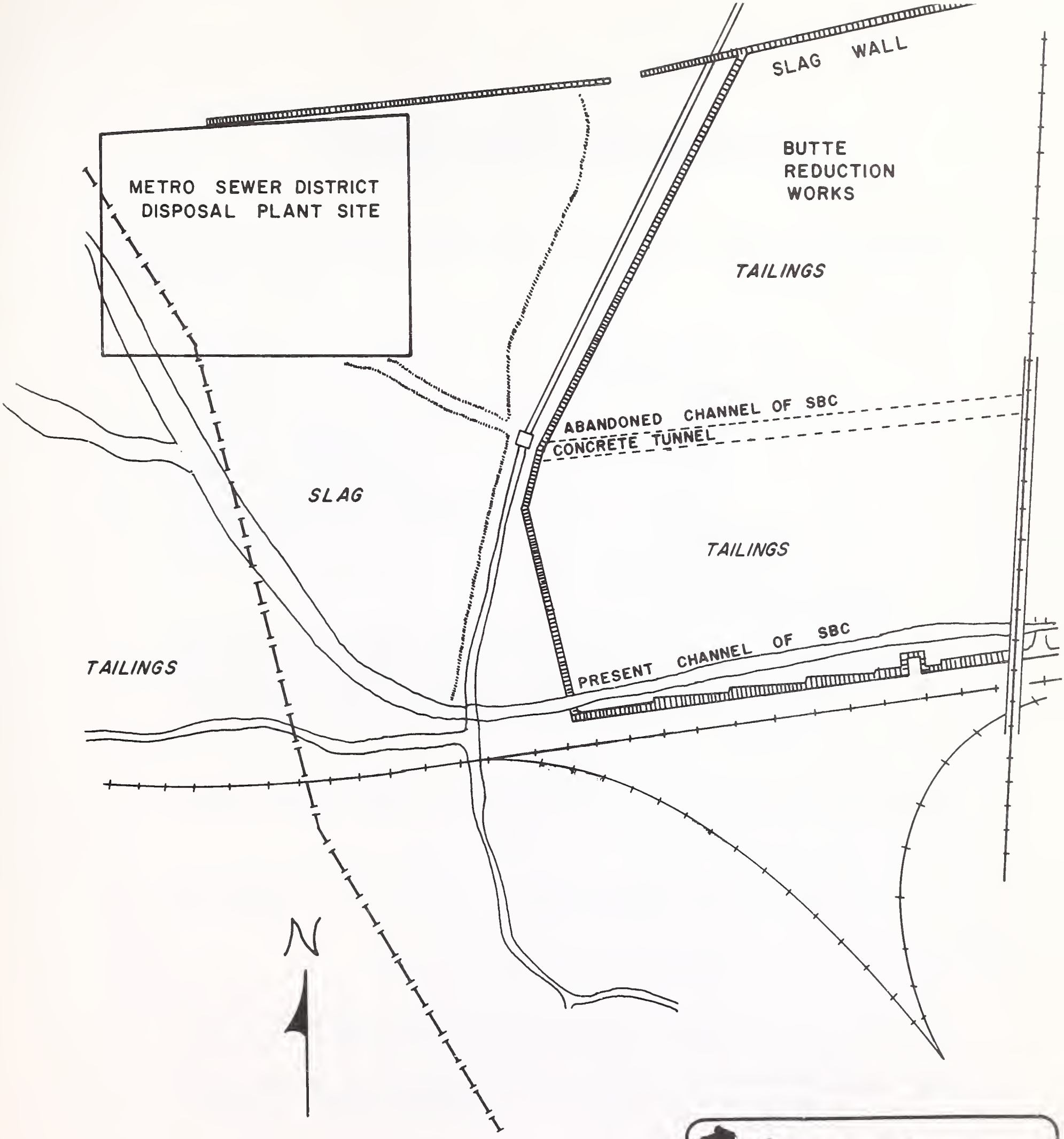
The numerous smelters along Silver Bow Creek used various methods to concentrate the ores (Smith 1952). The concentration process generally consisted of pulverizing the ore to sand or fine gravel-size particles and then using gravity methods to separate the particles high in metals from the waste rock or tailings (Smith 1952). From old photographs (James 1975; Freeman 1900) and maps of the area (Map 1-4), it is apparent that the tailings were deposited "out the back door" of the smelters and into the channel of Silver Bow Creek. Early records and maps also indicate that dams were built on the creek to contain the tailings. These dams occasionally would fail, as one above Meaderville (a Butte neighborhood) did in 1915, flooding Main Street of Meaderville and carrying large quantities of tailings down the creek to the lowlands and swamps below the town (GCM Services 1983).


LEGEND
SMELTER SITES
TAILINGS DEPOSITS
DUMPS
OTHER FACILITIES
SWAMPS
APPROX. CITY LIMITS
SILVER BOW MILL
BUTTE AND BOSTON
BUTTE SAMPLING WORKS
MONTANA ORE PURCHASING
CLARKS COLUSA
PITTSMONT
PARROT
MONTANA STREET
FRONT STREET
HARRISON AVE
ROCKER
ANACONDA POLE
TREATMENT PLANT
SILVERBOW
CR.
COLORADO SMELTER
BUTTE
REDUCTION
WORKS
BLACK
TAIL
CR.
SOURCE: USGS 1906
SILVER
BOW
CREEK
REMEDIAL INVESTIGATION
MAP 1-4
EARLY TAILINGS
DEPOSITS

Slag walls were poured at the Butte Reduction Works Smelter Site, apparently to contain the tailings from the milling operations of the plant. An artificial slag canyon was built for Silver Bow Creek west of Montana Street, and further downstream a concrete tunnel was built through which the stream discharged in 1914 (Map 1-5) (Meinzer 1914). Apparently no records were kept of the quantities of tailings which were deposited into the Silver Bow Creek channel by the various mills in the Butte area. However, an approximation of the volume of tailings can be made by using the total pounds of copper produced at the smelters and estimating an average grade of the ore delivered to the smelters from early assays of the ore. The total amount of copper produced by the smelters in the Butte area from 1880 to 1930 is 934 million pounds (Techlaw 1985; Historical Research Associates 1983). The grade of ore was variable, but ranged from 20% (high-grade ore) to less than 5% copper by weight (low-grade ore). Using a value of 5% and an ore density of 163 lb/ft^3, the maximum probable quantity of tailings produced by the smelters would have been 6.6×10^6 cubic yards of tailings (Table 1-6).

The tailings dumped into Silver Bow Creek contained high concentrations of many metals. This is indicated by chemical analyses of tailings material still present on the Silver Bow Creek floodplain (Duaime and others 1982; Thornell undated; Peckham 1979; SBC RI, Appendix B).

Table 1-7 gives estimates of volumes of waste/sediment deposits along Silver Bow Creek, the Warm Springs Ponds, and the upper Clark



Source: MEINZER 1914

SILVER BOW CREEK

REMEDIAL INVESTIGATION MAP 1-5

EARLY SILVER BOW CREEK DIVERSION AT MANGANEESE PLANT

TABLE 1-6
ESTIMATE OF VOLUME OF TAILINGS PRODUCED
BY BUTTE AREA SMELTERS, 1881-1930

Total pounds of Copper Produced - (data from Historical Research Associates 1983)

Smelter	Pounds Cu x 10^6
Parrot	174
MOP (Montana Ore Processing)	174
Clark's Colusa	32
Boston and Montana	91
Butte and Boston	129
Butte Reduction Works	111
Pittsmont	100 (est)
Colorado Smelting	123
	934×10^6 pounds

Estimated average grade of ore[a] = 5% Cu
Estimated density of mill tailings (wet) = 2.6 gm/cm^3
Estimated unit weight of tails = 2700 $pounds/yd^3$[b]
Estimated loss of ore to tails = 5%

$$\text{Total pounds ore} = \frac{(934 \times 10^6)}{.05} = 1.87 \times 10^{10} \text{ pounds}$$

Estimated loose volume of tails $= (0.9525)(1.87 \times 10^{10} \text{ pounds})$
$= 1.78 \times 10^{10}$ lbs.

$(1.78 \times 10^{10} \text{ lbs.})(1 \text{ yard}^3/2.7 \times 10^3 \text{ lbs.})$
$= 6.6 \times 10^6 \text{ yard}^3$

(a) Average grade of ore is an estimate based on the average ore grade in the 1930's. (Lemmon 1939)

(b) For loose, wet sand and clay materials. Caterpillar Tractor Company 1982, p.528.

TABLE 1-7
ESTIMATES OF VOLUMES OF WASTE DEPOSITS
ALONG SILVER BOW CREEK

Kaw Avenue - Silver Bow	175,000 yd^3
Colorado Tailings	250,000 yd^3
Silver Bow - Miles Crossing	1.5×10^6 yd^3
Miles Crossing - WSP	
Warm Springs Ponds	$19 \times 10^6 yd^3$
Warm Springs - Deer Lodge	$1.0 \times 10^6 yd^3$

Source: Hydrometrics 1983a, b, and c.

Fork River, totalling 21.95×10^6 cubic yards. If these volumes are compared with the volume of tailings previously estimated to have been produced by the smelters along Silver Bow Creek, 6.6 million cubic yards, it is evident that not all of the sediment deposits on the floodplain are tailings material.

Estimates of the total volume of tailings currently present along Silver Bow Creek from Kaw Avenue to Warm Springs Ponds vary from 1.3 to 2.7 million cubic yards (Hydrometrics 1983a). This estimate does not include the volume of tailings which underlies the City of Butte above Kaw Avenue, the material comprising the Colorado Tailings, or approximately 19 million cubic yards of sediment contained in Warm Springs Ponds 1, 2, and 3 (Hydrometrics 1983b).

1.3.5.2 Mine Waste Rock

Waste rock from the Butte area mines also may have been a significant sediment source impacting Silver Bow Creek. Waste rock typically was dumped around the mine shafts in the Butte Hill area. This material contained clay, silt, and sand-sized particles which were transported to Silver Bow Creek during periods of high precipitation and other runoff events. The waste rock contained higher concentrations of metals than other natural sediments derived from the valley area because of its association with the ore taken from the Butte mines (Hydrometrics 1983d). Metals were leached from the exposed waste rock by water and were transported, along with sediment, to Silver Bow Creek. Exact quantities of waste rock produced by the mines and the amount of sediment derived from this source are impossible to determine. The times of delivery of this sediment are unknown, but sediment production from the abandoned and inactive Butte mines still contributes contaminants to Silver Bow Creek (Thomas, Dean, and Hoskins Inc. 1984; Hydrometrics 1984).

1.3.5.3 Natural Sediment

Underground mining in the Butte area caused a significant environmental impact on the Summit Valley. Old photographs (James 1975) show large areas in the mountains and hills around Butte being clearcut to supply mining timbers and to fuel the smelters. Fumes from the smelters were very strong and undoubtedly contributed to vegetation loss on the hills around Butte (Smith 1952). Denudation

of the surrounding highlands greatly increased the sediment loads to streams and Silver Bow Creek. This sediment was mixed with tailings and waste rock sediment and was carried downstream. The quantity of material from this source is difficult to estimate. Studies of sediment production from areas undergoing urbanization and conversion of land from natural to agricultural uses indicate that sediment supply to streams increase from 10 to 100 times the original level (Dunne and Leopold 1978).

1.3.5.4 Flocculated Constituents

Along with the increased sediment load delivered to Silver Bow Creek, leaching of surface and ground water through tailings material and waste rock increased the dissolved constituent load of the creek. The precipitation plant effluent also contained dissolved constituents. As chemical equilibrium conditions of the creek changed downstream, the dissolved load may have precipitated from solution, to be deposited along with other sediment on the floodplains. Although minor in volume, this source of high metal concentration material probably further contaminated sediments already deposited.

1.3.5.5 Creek Morphology

The precise time periods and mechanisms of transport and deposition of tailings and other sediment by Silver Bow Creek are not clear. Generally, sediment is moved by streams as it is made available. If

too much sediment is available and the creek is unable to transport all of it, aggradation occurs, and a braided stream pattern may develop. By 1912, much aggradation of the Silver Bow Creek stream bed occurred at the confluence with Blacktail Creek (Meinzer 1914).

Other factors also influenced the morphology of Silver Bow Creek. Ground water from the mines was discharged to the creek, and water from the Big Hole River was diverted and pumped into the Silver Bow Creek drainage for domestic and commercial uses. Together these have increased the flow of Silver Bow Creek considerably above naturally occurring flows. Because of the many variables which are present, the factors which controlled Silver Bow Creek morphology are difficult to identify. A likely sequence of events which may have occurred along Silver Bow Creek is as follows:

1880-1930	Introduction of large quantities of sediment into the Silver Bow Creek channel (mill tailings, waste rock dumps, and "natural" sediment). Aggradation of the stream, filling of the natural stream channel, braided stream pattern develops.
1880-Present	Mine pumping, Big Hole River water and Silver Lake process water added to Silver Bow Creek (enabling more sediment to be carried). Sediment is carried downstream by natural stream processes including normal flow and flood events, excepting as affected by the Warm Springs Ponds. Braided stream pattern moves downstream as some of the increased sediment load is deposited downstream, clogging the channel.
1918	Warm Springs Ponds 1 and 2 begin catching wastes and sediment.
1935	Channelization of upper portions of Silver Bow Creek channel; isolation of tailings; reduction in sediment supply.

1947	Significant quantities of sediment still available to the stream from downstream deposits - some sections by Ramsay are still braided.
1955	Reformation of an incised stream channel; erosion of stream banks.
1963- 1983	Weed Concentrator built - increased flow in Silver Bow Creek - more incision of stream channel, continued erosion of stream banks.

DRAFT

2.0 HAZARDOUS SUBSTANCES INVENTORY

USEPA identified six major metal contaminants in Silver Bow Creek/ Upper Clark Fork River: arsenic, cadmium, copper, lead, iron, and zinc (CH_2M Hill 1983). These contaminants enter the drainage system primarily by ground-water seepage and storm-water runoff in the upper basin. The ground water and surface runoff pick up these contaminants from various deposits of mine waste rock, mill tailings, and precipitates throughout the SBC RI study area. In this chapter, the waste types causing contamination of the creek and floodplain are discussed, followed by a description of the occurrence and possible hazards associated with each metal contaminant.

2.1 WASTE TYPES

The waste type associated with the ground-water seepage was determined to be mill tailings from early ore beneficiation in the Butte area. The waste type associated with the storm-water runoff was not determined during this RI, as only the storm-water inputs to Silver Bow Creek were investigated and upstream studies were not implemented. However, waste materials from mining activities in the upper basin were suspected as the source of contaminants to the storm water.

Contamination of soils in the Silver Bow Creek and upper Clark Fork River floodplains occurred as a result of deposition of mill tailings and mining waste materials.

Mill tailings from early ore beneficiation activities in Butte were either dumped in settling ponds in the Silver Bow Creek floodplain or were discharged directly to the creek. Early tailings ponds occasionally failed, releasing material to the creek. Mining waste materials were washed into the creek by uncontrolled surface runoff. These materials were mixed with natural stream sediments and were redeposited in the floodplain of Silver Bow Creek and the upper Clark Fork River by fluvial action.

Four waste types were identified as contributing or potentially contributing to the contamination of the Silver Bow Creek site:

- Impounded Tailings. This waste type included both covered mill tailings, such as the Parrot Smelter Tailings, and uncovered mill tailings, such as the Colorado Tailings.
- Fluvial Mixed Deposits. This waste type consisted of mill tailings, mine waste rock, natural sediments, and precipitates mixed together and deposited by fluvial action.
- Mine Waste Rock Dumps. Located in the upper basin, this waste type was suspected, but not determined, as a source of contamination to surface water runoff.
- Warm Springs Ponds Sediments. This waste type was a mixture of mill tailings, mine waste rock, natural sediments, and precipitates.

2.1.1 Impounded Mill Tailings

2.1.1.1 Location

Three deposits of impounded, in-place mill tailings were identified during the SBC RI. These were the Parrot Smelter Tailings, located

at the upper end of the MSD; the Butte Reduction Works Tailings, located just west of Montana Street in Butte; and the Colorado Tailings. The Parrot Smelter Tailings were covered with alluvial fill material and were not visible. Portions of the Butte Reduction Works Tailings were visible, but much was covered. Most of the Colorado Tailings were visible, but a small portion on the northwest side of Silver Bow Creek was covered with alluvial fill material.

2.1.1.2 Waste Components

Mill tailings result from the concentration or beneficiation of metal-bearing ores. The process involves crushing the mined ore, then milling the crushed rock to a fine particle size, mixing the fine particles with water and various reagents which float the metals of interest, drawing off the top concentrate, and disposing of the remains. These remains are known as mill tailings.

Milling techniques used in Butte varied over the years. These changes primarily affected the efficiency of metal recovery in the concentrates and the particle size of the waste tailings.

Mill tailings contain metals concentrations higher than natural sediment metal concentrations due to the original mineralization of the ore and the failure of the beneficiation process to remove all of the metals. The high concentration of metals in the ores and the less than 100% effective metal removal processes result in mill

tailings with concentrations from ten to a hundred times greater than natural sediments.

The impounded mill tailings deposits in the SBC area consisted of finely ground sandy materials with high metal concentrations. The most significant metals included arsenic, cadmium, copper, lead, iron, and zinc.

The best example of this type of waste material was the Colorado Tailings, located on Silver Bow Creek, west of Montana Street in Butte. The Colorado Tailings material was found to be approximately 90% sand-size particles with a pH range of 2.7 to 4.0. Plant-toxic levels of aluminum, arsenic, copper, and zinc were found in the tailings (Intra Search 1984). Total concentrations of gold, silver, copper, and lead in the Colorado Tailings averaged 0.0059 oz/ton, 1.17 oz/ton, 1829 µg/g, and 682 µg/g, respectively (Duaime et al. 1982).

The Parrot Tailings and Butte Reduction Works Tailings were not adequately sampled during the SBC RI to characterize them precisely. Further studies are recommended to delineate and characterize these deposits.

2.1.1.3 Waste Amounts

Insufficient data were available to calculate the volume of the Parrot tailings deposit and the Butte Reduction Works tailings

deposit. Estimated total tailings production from the Parrot Smelter and the Butte Reduction Works were estimated to be slightly less than 790,000 cubic yards and 500,000 cubic yards, respectively (Section 1.3.5). However, some of the original tailings may have not been impounded, so the actual volume deposited in the impoundments may have been less. Studies to further define and delineate these tailings deposits are recommended.

The Colorado Tailings area has been estimated to contain 242,000 cubic yards of material, which is what remained following removal and processing of some of the original waste deposit. The original deposit was estimated to contain slightly less than 559,000 cubic yards of waste material (Duaime et al. 1982).

2.1.2 Fluvial Mixed Deposits

2.1.2.1 Location

Deposits of mill tailings, mine waste materials, natural sediment, and precipitates occurred within the floodplain of Silver Bow Creek and the upper Clark Fork River from just below the Colorado Tailings in Butte to the study area boundary north of Deer Lodge. These mixtures also occurred downstream of the study area boundary. These deposits occurred within all of the floodplain from Butte to Warm Springs. Below Warm Springs the deposits were spotty, occurring at inside bends of the Clark Fork River. The Ramsay Flats were the

single largest deposit of this type. Visible deposits were mapped for the SBC RI; maps are found in Appendix D, Part 2.

2.1.2.2 Waste Components

These waste deposits consisted of mill tailings, mine waste rock, and natural sediments. No significant particle size differentiation or chemical characteristics in relation to distance from Butte were detected. However, particle size distribution was affected by stream gradient, with heavier particles more prevalent in the higher energy reaches of the creek. These deposits were different from the Colorado Tailings deposit in their texture, averaging a sand content of 55% and a clay content of 10%.

These deposits exhibited an average pH of 4.73 and an average specific conductivity of 5860 µmhos/cm; total sulfur averaged 0.5%. Total copper concentration was 2350 µg/g; cadmium, 13.4 µg/g; iron, 18,620 µg/g; lead, 989 µg/g; manganese, 2237 µg/g; zinc, 3070 µg/g; and arsenic, 399 µg/g. Water-soluable concentrations in tested SBC RI tailings samples were copper, 20 µg/g; cadmium, 0.54 µg/g; lead, 0.72 µg/g; manganese, 26.3 µg/g; and zinc, 36.3 µg/g.

Detailed discussions of the chemistry of these elements within the deposits are in Appendix B, Ground Water and Tailings Investigation Report.

2.1.2.3 Waste Amounts

A total of 4,250,000 cubic yards of mixed tailings, mine waste rock, natural sediments, and precipitates were estimated to occur along Silver Bow Creek from Butte to Warm Springs and along the upper Clark Fork River from Warm Springs to Deer Lodge, Montana (See Section 1.3.5). Over 1,100 acres of visible waste deposits were mapped by the SBC RI (See Appendix D, Part 2).

2.1.3 Mine Waste Rock

2.1.3.1 Location

Mine waste rock, located in and near the historic mining district of Butte, was suspected as a source of contaminants found in the storm-water runoff during the SBC RI. However, SBC RI data were insufficient to precisely assign these waste materials as the source of storm-water contamination. Further studies to determine the location of the source of this contamination are recommended.

2.1.3.2 Waste Components

Waste rock dumps located adjacent to or near the abandoned mines in the upper drainage area of Silver Bow Creek were not sampled during the SBC RI, so no data were developed on their composition. However, previous sampling of some of these dumps indicated that most of them contain high (greater than geochemical background) levels of

metals (Hydrometrics 1983d). Investigations of the sources of contamination in storm-water runoff are recommended. These studies should further characterize the waste rock dumps if these prove to be the source of contamination.

2.1.3.3 Waste Amounts

Previous investigations estimated the total volume of abandoned waste rock dumps in the upper Silver Bow Creek drainage to be approximately 9,706,620 cubic yards (Hydrometrics 1983d). SBC RI investigations did not study these potential contaminant sources. Further studies are recommended.

2.1.4 Warm Springs Ponds Sediments

2.1.4.1 Location

Ponds located at Warm Springs, Montana, are used to treat Silver Bow Creek water prior to release to the upper Clark Fork River. Since 1959, lime has been added to pond inputs, to aid in the precipitation of dissolved metals.

The waste material collected by the ponds consisted of a mixture of mill tailings, mine waste rock, and natural sediments carried by Silver Bow Creek and materials deposited by the precipitation reactions resulting from lime-induced and natural pH changes.

2.1.4.2 Waste Components

Averages of SBC RI samples of Warm Springs Ponds 2 and 3 bottom sediments are shown in Table 2-1. The values shown are 10 to 100 times greater than these found in natural lake bed sediments from the region.

Sediment samples from the ponds had relatively low percent solids, averaging 17% in Pond 3 and 34% in Pond 2. The dissolved metal concentrations in pore water associated with Ponds 2 and 3 samples are in Table 2-2.

2.1.4.3 Waste Amounts

Previous investigators have estimated that the Warm Springs Ponds contain approximately 19 million cubic yards of mixed tailings, mine waste rock, natural sediments, and precipitates (Hydrometrics 1983b). Further investigations are recommended to verify this number.

2.2 WASTE COMPONENT CHARACTERISTICS AND BEHAVIOR

The waste types described contaminate the environment through the release of metals. The contaminants in the study area found during the SBC RI were arsenic, cadmium, copper, iron, lead, zinc, and pentachlorphenol. The metal contaminants were found in both solid

TABLE 2-1
TOTAL METAL AVERAGES OF WARM SPRINGS PONDS 2 AND 3
BOTTOM SEDIMENTS (PPM DRY WEIGHT)

POND	METAL (TOTAL)					
	As	Cd	Cu	Pb	Fe	Zn
2	294	103	3,940	542	71,000	12,100
3	422	193	5,170	183	95,300	32,300

TABLE 2-2
DISSOLVED METAL CONCENTRATIONS IN PORE WATER FROM
WARM SPRINGS PONDS 2 AND 3 (mg/L)

POND	METAL (DISSOLVED)					
	As	Cd	Cu	Pb	Fe	Zn
2	0.024	0.0006	0.027	0.002	0.360	0.191
3	0.011	0.0009	<0.011	<0.001	<0.01	0.002

forms and dissolved forms. Pentachlorophenol (PCP) was not investigated during this RI study as the PCP source was removed from the SBC RI study area and given separate CERCLA site status. The sources, transport, and fate of the metals were investigated by the SBC RI.

To evaluate remedial actions on a CERCLA site, the toxicity, transport characteristics, potential for bioaccumulation, potential for environmental transformation, potential for further off-site migration and effects to beneficial use were characterized for each contaminant identified for the site. The major pathway for contaminant migration in the SBC RI site is by water (See Chapter 1.0 of this report).

2.2.1 Chemical Characteristics

2.2.1.1 Arsenic

Arsenic and its associated compounds were used in the SBC RI site by wood treatment plants, and arsenic also is a byproduct from the mining and milling of metal-bearing ores as a naturally occurring mineral. It is found in the Earth's crust at 1.8 mg/kg, soil at 6.0 mg/kg, in the ocean at 0.003 mg/L, and in unpolluted freshwater at 0.0004 mg/L (USEPA 1981).

Arsenic can exist in the natural environment in four oxidation states (+5, +3, 0, -3) as inorganic and organic species in dissolved and

gaseous states. Arsenic as a free element (oxidation state = 0) is rarely encountered in natural waters and has a low toxicity due to its very low solubility. However, oxidized arsenic (arsenate, +5; arsenite, +3) is soluble in water, with inorganic arsenates predominating over inorganic arsenites under normal oxidizing conditions, because arsenate is more thermodynamically stable than arsenite (USEPA 1980b). Dissolved arsenate and arsenite can be removed from water by coprecipitation or adsorption.

2.2.1.2 Cadmium

Cadmium and its associated compounds are used in many industries and occur as a by-product or constituent in many manufactured or processed items. Cadmium is also a by-product or is found in the waste material from mining and milling, as it is a naturally occurring element found in the Earth's crust at approximately 0.55 mg/kg (Lee 1972). In natural unpolluted waters cadmium sometimes occurs at concentrations less than 0.01 µg/L, but in environments impacted by man, concentrations can be several µg/L or greater (USEPA 1985d).

Free divalent cadmium is the most common form of cadmium found in well oxygenated freshwaters. Precipitation as a carbonate or hydroxide occurs at moderately alkaline pHs (8-9). Particulate matter and dissolved organic material may bind substantial portions of available dissolved cadmium (USEPA 1985d).

2.2.1.3 Copper

Copper and its associated compounds are important base materials of the industrialized world. Copper has been mined, milled, and refined for over 5,000 years (CRC 1981). The most important copper ores are the sulfides, oxides, and carbonates, and the Butte copper ores were copper sulfides. Because milling and smelting are not 100% efficient in partitioning copper, the waste products from these processes contain copper. Copper is found in the Earth's crust, soil, the ocean, and fresh water at average concentrations of 55, 20, 0.003, and 0.01 ppm, respectively (CRC 1981).

The divalent cupric ion is the most common form of copper found in natural waters. However, this form, which is the toxic form, complexes easily with other molecules, thus effectively reducing its toxicity. Copper is a necessary nutrient for both plants and animals, but in aquatic systems, copper is toxic at levels only slightly higher than nutrient levels. Unpolluted surface waters in the United States show a range of copper concentrations of 1-10 µg/L (USEPA 1985e).

2.2.1.4 Iron

Iron and its various alloys are important base materials of the industrialized world. Iron is the fourth most abundant element, by weight, making up the crust of the earth (CRC 1981). Because iron

is so abundant, it is often found in the waste materials from mining and milling of ores for other metals.

The principal factors controlling the form of iron in aquatic systems are pH, Eh, dissolved CO_2, and the sulfur species. The interaction of these factors and the resulting iron forms are fairly complex.

Detailed discussion of aquatic iron chemistry can be found in Stumm and Morgan (1981). In general, if Eh, CO_2, and sulfur species remain constant, low pH's are required to keep iron in a dissolved form. The water of a flowing stream with a near neutral pH, even when grossly polluted, cannot contain significant concentrations of uncomplexed dissolved ferrous iron at equilibrium. Iron normally present in such water occurs either as particulate ferric hydroxide or as some form of organic complex or slowly reacting dissolved ferrous (Fe^{2+}) iron.

2.2.1.5 Lead

Lead, along with iron and copper, was mined and refined by early civilizations. Lead is found in the waste material of the mining and milling of other ores, as lead is a common constituent of the Earth's crust, occurring at an average concentration of 12.5 mg/kg (USEPA 1981). In soil, oceans, and freshwater, lead concentrations average 10 mg/kg, 0.00003 mg/L, and 0.005 mg/L, respectively (USEPA 1981).

Lead exists in nature primarily as lead sulfide (galena), lead carbonate (cerussite), lead sulfate (anglesite), and lead chlorophosphate (pyromorphite). These lead compounds have very low solubilities (USEPA 1976b). Stable lead complexes result from the interaction of lead with the sulfhydryl, carboxyl, and amine coordination sites found in living organisms.

2.2.1.6 Zinc

Zinc, like iron and copper, has a long history of use by man. The principal forms of zinc are sphalerite (zinc sulfide), smithsonite (zinc carbonate), calamine (zinc silicate) and Franklinite (zinc, manganese, and iron oxides). The primary form of zinc found in the Butte ores is sphalerite. Zinc was mined and milled in Butte during the early history of Butte and was also found as a secondary element in copper ores.

Zinc and cadmium exhibit similar chemistries due to their similar atomic structure. In aqueous solutions zinc always has a valence of +2, and exhibits amphoteric properties, dissolving in acids to form hydrated Zn (II) cations and in strong bases to form zincate anions such as $Zn(OH)^{-2}$. Compounds of zinc with the common ligands of surface waters are soluble in neutral and acid solutions, so that zinc is readily transported in the dissolved state. Zinc is one of the most mobile heavy metals due to this characteristic (USEPA 1980d). The hydrated cation (Zn++) remains the dominant species up to a pH of 8. Adsorbed zinc is less toxic than dissolved zinc (USEPA 1980d).

2.2.2 Aquatic Toxicology

The toxicity of arsenic, cadmium, copper, iron, lead, or zinc in natural waters is dependent on the form in which the contaminant occurs. The characteristics of the natural water that determine the forms of these contaminants include pH, Eh, organic content, suspended sediment load, sediment characteristics, and concentrations of chloride, sulfate, carbonate, hydroxide, magnesium plus calcium (hardness), and phosphate.

The USEPA recommends that for the protection of aquatic life the concentrations of total recoverable arsenic, cadmium, copper, lead, and zinc, in natural waters should not exceed specific criteria. The Montana Department of Health and Environmental Sciences has adopted these criteria, and also has published a water quality criteria for iron (MDHES 1986). Criteria for arsenic, cadmium, copper, lead, and zinc have been established for a one-hour average concentration (acute) and a four-day average concentration (chronic). Table 2-3 shows the number of times the USEPA one-hour or MDHES criteria was exceeded by arsenic, cadmium, copper, iron, lead, and zinc at each surface water station sampled during the SBC RI. For comparison, the number of measurements of a contaminant are also indicated.

The USEPA recommends the criteria be compared to acid-soluble measurements. However, the USEPA, recognizing that an acid-soluble method has not been formally adopted, suggests that the criteria be

TABLE 2-3
RI ONE HOUR AQUATIC LIFE CRITERIA EXCEEDENCES

Station	As(a)		Cd(b)		Cu(c)		Fe(d)		Pb(e)		Zn(f)	
	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex
*PS-0A	2	0	2	2	2	2	2	0	2	2	2	2
*PS-01	1	1	1	1	1	1	1	0	1	1	1	1
*PS-02	2	0	2	1	2	1	2	0	2	1	2	2
*PS-03	1	0	1	1	1	0	1	0	1	1	1	0
*PS-04	8	0	8	3	9	8	8	0	8	2	9	8
*PS-07	0	0	0	0	0	0	0	0	0	0	0	0
*PS-08	16	0	16	2	20	3	18	0	16	0	20	4
PS-08A	3	0	3	0	3	0	3	0	3	0	3	0
PS-10	13	0	13	0	13	0	3	0	13	0	13	0
PS-11	15	0	15	0	15	1	15	0	15	0	15	0
PS-11A	17	0	17	0	17	2	17	0	17	0	17	1
PS-12	16	0	16	0	16	3	16	0	16	0	16	4
*PS-13	11	1	11	0	11	0	11	0	11	0	11	0
*SS-02	6	0	6	3	6	5	6	1	6	0	6	6
*SS-03	15	0	15	6	15	12	14	9	15	1	15	14
*SS-04	16	0	16	0	17	3	16	0	16	1	17	0
SS-05	14	0	14	0	14	2	14	0	14	0	14	11
SS-06	6	0	6	0	6	5	6	0	6	0	6	5
*SS-07	16	0	16	1	17	16	16	0	16	2	17	16
SS-08	14	0	14	0	14	13	14	0	14	0	14	13
SS-09	13	0	13	0	13	13	13	0	13	0	13	12
SS-10	7	0	7	1	7	6	7	0	7	0	7	6
SS-11	15	0	15	1	15	14	15	0	15	0	15	14
SS-12	14	0	14	1	14	6	14	0	14	1	14	5
SS-13	15	0	15	1	15	14	15	0	15	0	15	13
SS-14	14	0	14	0	14	13	14	0	14	0	14	11
SS-15	15	0	15	0	15	1	15	0	15	0	15	0
SS-16	15	0	15	0	15	11	15	0	15	2	15	11
SS-17	11	0	11	0	11	8	11	0	11	0	11	6
SS-18	14	0	14	0	14	0	14	0	14	0	14	0
SS-19	12	0	12	0	12	12	12	0	12	0	12	6
*SS-20	15	0	15	0	15	2	15	0	15	0	15	6
SS-21	17	0	17	0	17	4	17	0	17	0	17	6
SS-22	18	0	18	0	18	3	18	0	18	0	18	4

TABLE 2-3
RI ONE HOUR AQUATIC LIFE CRITERIA EXCEEDENCES (Continued)

Station	As(a)		Cd(b)		Cu(c)		Fe(d)		Pb(e)		Zn(f)	
	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex
SS-23	15	0	15	0	15	0	15	5	15	0	15	0
SS-24	15	0	15	0	15	0	15	1	15	0	15	0
SS-25	15	0	15	0	15	1	15	0	15	0	15	1
SS-26												
SS-27	8	0	8	0	8	0	8	2	8	0	8	0
SS-27A	9	0	9	0	9	0	9	6	9	0	9	0
SS-28	13	0	13	0	13	0	13	0	13	0	13	0
SS-29	15	0	15	0	15	0	15	0	15	0	15	0
SS-30	2	0	2	0	2	0	2	0	2	0	2	0
SS-31	2	0	2	0	2	0	2	0	2	0	2	0
**SS-32	2	0	2	0	2	0	2	0	2	0	2	0
SS-33	2	0	2	0	2	0	2	0	2	0	2	0
SS-34	2	0	2	0	2	0	2	0	2	0	2	0
SS-35	2	0	2	0	2	0	2	0	2	0	2	0
SS-36	2	0	2	0	2	0	2	0	2	0	2	0

Note: Station locations are shown on map 3-1.

(a) Criteria (mg/L) = .360 USEPA 1985c
Compared to total As concentrations.

(b) Criteria (mg/L) = $(e^{(1.28[\ln(\text{hardness})-3.828])})(0.001)$ USEPA 1985d.
Compared to Total Cd concentrations.

(c) Criteria (mg/L) = $(e^{(0.9422[\ln(\text{hardness})-1.464])})(0.001)$ USEPA 1985e.
Compared to Dissolved Cu concentrations.

(d) Criteria (mg/L) = 1.0 MDHES 1986
Compared to Dissolved Fe concentrations.

(e) Criteria (mg/L) = $(e^{(1.268[\ln(\text{hardness})-1.416])})(0.001)$ USEPA 1985f.
Compared to Total Pb concentrations.

(f) Criteria (mg/L) = $(e^{(0.8213[\ln(\text{hardness})]+0.8141)})(0.001)$ USEPA 1986b.
Compared to Dissolved Zn concentrations.

* Includes duplicates and or storm runoff sampling.
** Does not include samples collected during bioassay test.

Measurements less than detectable were counted as less than the criteria even if the detection limit was above the criteria.

compared to total recoverable measurements until an acid-soluble method is approved.

During the SBC RI planning in 1984 the determination of measurement methods was driven by human health concerns (drinking water standards) and determination of contaminant transport mechanisms. For these reasons, total and dissolved measurements were planned. Additionally, arsenic, cadmium, and lead were measured only by the total method. These data constraints complicate efforts to compare the SBC RI data to aquatic life water quality criteria.

The criteria, as applied in Table 2-3, may show exceedences in total arsenic, cadmium, or lead where a total extractable method may not have shown an exceedence. Using the dissolved measurement of copper, iron, and zinc for comparison may actually show fewer exceedences than would have occurred using a total extractable measurement. These caveats should be kept in mind while evaluating the data presented in Table 2-3.

Fish bioassay studies performed at Deer Lodge in May of 1985 as part of the SBC RI showed no toxic effects on the test organisms by the water of the upper Clark Fork River. Copper occasionally was found to exceed the acute or chronic criteria during the bioassay test, but these exceedences apparently were not toxic enough to affect the mortality of the test organisms.

2.2.3 Human Toxicology

Arsenic has chronic and acute effects on humans. Acute effects manifest themselves through enzyme inhibition and enzyme activation, causing related systematic disorders. The lethal dose for trivalent arsenic oxide has been estimated to be 70 - 180 mg. Sub-lethal doses of arsenic cause anemia, leukopenia, and skin lesions. Chronic exposure to arsenic has also been shown to be related to cancer and teratogenic effects (USEPA 1980b). The USEPA has established 0.050 mg/L total arsenic as the maximum contaminant level allowed in public drinking water (40CFR 141).

Cadmium exhibits acute and chronic effects on humans, depending on the dose and length of exposure. Cadmium toxicity symptoms include kidney damage, protein uria, glucosunia, and aminoaciduria (Lappenbusch 1986). For cadmium the World Health Organization (WHO) and the Canadian Health and Welfare Service recommend a maximum acceptable concentration of 0.005 mg/L as the maximum contaminant level allowed in drinking water (40 CFR 141). The USEPA allowable contaminant level (.01 mg/L) is based on the total measurement of cadmium.

Copper is an essential element in human metabolism. Suggested daily intakes for infants, children, and adults are 0.7, 2, and 2 mg, respectively. Disorders caused by copper toxicity include Wilson's disease (disorder of copper metabolism) and hepatic cirrhosis. The USEPA, Canadian Health and Welfare Service, and WHO have all established drinking water criteria of 1.0 mg/L (Lappenbusch 1986).

Because iron is an essential element in human metabolism, recommended daily intakes of iron for infants, children, and adults are 12, 12, and 14 mg, respectively. The average daily intake of iron by American adults is 20 mg (Lappenbusch 1986). Gastrointestinal irritation may occur from intake of high amounts of iron. WHO, USEPA, and the Canadian Health and Welfare Service have established an aesthetic guide (or standard) of 0.30 mg/L. The Canadian Health and Welfare Service has established <0.05 mg/L as their objective concentration of iron (Lappenbusch 1986). These guides or objectives have been established to protect the taste of water, not the health of the consumer.

Lead is a major contaminant of concern due to its now ubiquitous distribution in the environment caused by centuries of use by man. Current daily ambient intakes by Americans have been estimated at 0.068, 0.050, and 0.001 mg by water, food, and air, respectively (Lappenbusch 1986). Acute lead intoxication causes anemia, neurological dysfunction, and kidney impairment. Chronic lead exposure at subacute levels are suspected of causing impaired neurologic and kidney function (USEPA 1976b). The USEPA interim drinking water standard, WHO guide, and Canadian Health and Welfare Service health limit are established at 0.05 mg/L (Lappenbusch 1986). These limits are established using total concentration of lead as the analytical method.

Zinc is a required element for human metabolism but in large doses toxic effects occur. Suggested infant, child, and adult daily

intakes of zinc are 7, 15, and 15 mg, respectively; American adults are estimated to consume 13 mg/day (Lappenbusch 1986). Zinc toxicity expresses itself in irritability, muscle stiffness, muscle pain, loss of appetite, and nausea. The WHO's aesthetic level, the USEPA secondary standard, and the Canadian Health and Welfare aesthetic guide are all 5.0 mg/L total zinc in drinking water (Lappenbusch 1986).

Tables 2-4 and 2-5 show the number of SBC RI water samples exceeding the primary and secondary standards for drinking water at each of the surface and ground-water sampling sites. Also shown in these tables are the total number of SBC RI measurements at each site for total arsenic, cadmium, copper, iron, lead, and zinc.

2.2.4 Transport Characteristics

Contaminants introduced into an aquatic environment will be partitioned, with certain percentages of the introduced contaminant having a particular form depending on the form introduced and the chemical, physical, and biological characteristics of the receiving system.

TABLE 2-4
SBC RI SURFACE WATER DRINKING WATER STANDARD EXCEEDENCES

Station	Total As[a]		Total Cd[b]		Total Cu[c]		Total Fe[d]		Total Pb[e]		Total Zn[f]	
	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex
*PS-0A	2	1	2	0	2	0	2	2	2	2	2	0
*PS-01	1	1	1	1	1	1	1	1	1	1	1	1
*PS-02	2	2	2	1	2	1	2	1	2	1	2	1
*PS-03	1	1	1	1	1	0	1	1	1	1	1	0
*PS-04	8	1	8	2	9	0	8	7	8	5	9	0
*PS-07	0	0	0	0	0	0	0	0	0	0	0	0
*PS-08	16	0	16	1	20	1	18	3	16	0	25	2
PS-08A	3	0	3	0	3	0	3	0	3	0	3	0
PS-10	13	0	13	0	13	0	13	0	13	0	13	0
PS-11	15	0	15	0	15	0	15	0	15	0	15	0
PS-11A	17	0	17	0	17	0	17	0	17	0	17	0
PS-12	16	0	16	0	16	0	16	9	16	0	16	0
*PS-13	11	0	11	0	21	0	11	3	11	1	11	0
*SS-02	6	0	6	2	6	2	6	5	6	1	6	2
*SS-03	15	1	15	12	16	4	14	15	15	2	16	14
*SS-04	16	0	16	0	17	0	16	14	16	1	17	0
SS-05	14	0	14	0	14	0	14	13	14	1	14	0
SS-06	6	0	6	0	6	0	6	5	6	0	6	0
*SS-07	16	1	16	1	17	1	16	16	16	3	17	0
SS-08	14	0	14	0	14	0	14	13	14	1	14	0
SS-09	13	0	13	0	13	0	13	13	13	1	13	0
SS-10	7	0	7	0	7	0	7	6	7	1	7	0
SS-11	15	1	15	0	15	0	15	14	15	1	15	0
SS-12	14	1	14	1	14	1	14	10	14	3	14	2
SS-13	15	0	15	1	15	0	15	14	15	1	15	0
SS-14	14	0	14	0	14	0	14	13	14	1	14	0
SS-15	15	0	15	0	15	0	15	0	15	0	15	0
SS-16	15	0	15	0	15	0	15	14	15	3	15	0
SS-17	11	0	11	0	11	0	11	10	11	0	11	0
SS-18	14	1	14	0	14	0	14	3	14	0	14	0
SS-19	12	0	12	0	12	0	12	12	12	0	12	0
*SS-20	15	1	15	0	15	0	15	10	15	0	15	0
SS-21	17	0	17	0	17	0	17	16	17	0	17	0
SS-22	18	0	18	0	18	0	18	12	18	0	18	0

TABLE 2-4
SBC RI SURFACE-WATER DRINKING WATER STANDARD EXCEEDENCES (Continued)

	Total As[a]		Total Cd[b]		Total Cu[c]		Total Fe[d]		Total Pb[e]		Total Zn[f]	
Station	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex
SS-23	15	0	15	0	15	0	15	13	15	1	15	0
SS-24	15	0	15	0	15	0	15	11	15	1	15	0
SS-25	15	0	15	0	15	0	15	12	15	0	15	0
SS-26												
SS-27	8	0	8	0	8	0	8	7	8	0	8	0
SS-27A	9	4	9	0	9	0	9	6	9	0	9	0
SS-28	13	0	13	0	13	0	13	3	13	0	13	0
SS-29	15	1	15	0	15	0	15	10	15	0	15	0
SS-30	2	0	2	0	2	0	2	1	2	0	2	0
SS-31	2	0	2	0	2	0	2	1	2	0	2	0
SS-32	2	0	2	0	2	0	2	1	2	0	2	0
SS-33	2	0	2	0	2	0	2	1	2	0	2	0
SS-34	2	0	2	0	2	0	2	1	2	0	2	0
SS-35	2	0	2	0	2	0	2	1	2	0	2	0
SS-36	2	0	2	0	2	0	2	1	2	0	2	0

Note: Sample sites are shown on Map 3-1.

(a) Primary standard = 0.05 mg/L (MDHES 1986)

(b) Primary standard = 0.01 mg/L (MDHES 1986)

(c) Secondary standard = 1.0 mg/L (MDHES 1986)

(d) Secondary standard = 0.3 mg/L (MDHES 1986)

(e) Primary standard = 0.05 mg/L (MDHES 1986)

(f) Secondary Standard = 5.0 mg/L (MDHES 1986)

*Includes duplicates and storm run-off sampling
**Does not include samples collected during bioassay test.

TABLE 2-5
SBC RI GROUND-WATER DRINKING WATER STANDARD EXCEEDENCES

Station	Diss As		Diss Cd		Diss Cu		Diss Fe		Diss Pb		Diss Zn	
	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex
DW-101	2	0	2	2	2	2	2	2	2	0	2	2
DW-102	3	0	3	3	3	0	3	3	3	0	3	3
DW-103	2	0	2	0	2	0	2	1	2	0	2	0
DW-105	4	0	4	4	4	0	4	4	4	0	4	4
DW-106	2	0	2	1	2	0	2	2	2	0	2	0
DW-107	3	0	3	0	3	0	3	3	3	0	3	0
DW-108	1	0	1	1	1	0	1	0	1	0	1	1
DW-109	3	2	3	1	3	0	3	3	3	0	3	1
DW-110	3	1	3	0	3	0	3	3	3	0	3	3
DW-111	2	0	2	0	2	0	2	0	2	0	2	0
DW-112	4	0	4	1	4	0	4	4	4	0	4	0
DW-114	3	0	3	1	3	0	3	2	3	0	3	0
DW-115	3	0	3	0	3	0	3	0	3	0	3	0
DW-116	4	0	4	4	4	0	4	4	4	0	4	0
DW-117	1	0	1	0	1	0	1	0	1	0	1	0
DW-118	3	1	3	0	3	0	3	3	3	0	3	0
DW-119	4	2	4	0	4	0	4	4	4	0	4	0
DW-121	4	0	4	0	4	0	4	0	4	0	4	0
DW-122	1	0	1	0	1	0	1	0	1	0	1	0
DW-123	1	0	1	0	1	0	1	0	1	0	1	0
DW-124	2	0	2	0	2	0	2	0	2	0	2	0
DW-125	1	0	1	0	1	0	1	0	1	0	1	0
DW-128	2	0	2	0	2	0	2	0	2	0	2	0
DW-129	2	0	2	0	2	0	2	0	2	0	2	0
DW-130	3	0	3	1	3	0	3	0	3	0	3	0
DW-131	3	0	3	0	3	0	3	1	3	0	3	0
DW-132	1	0	1	1	1	0	1	0	1	0	1	1
DW-133	2	0	2	0	2	0	2	0	2	0	2	0
DW-134	2	0	2	2	2	0	2	0	2	0	2	2
DW-135	2	0	2	0	2	0	2	0	2	0	2	0
DW-136	1	0	1	1	1	1	1	1	1	1	1	1
DW-137	2	0	2	2	2	2	2	2	2	2	2	2
DW-202	1	0	1	0	1	0	1	0	1	0	1	0
DW-203	2	0	2	0	2	0	2	0	2	0	2	0
DW-204	2	0	2	0	2	0	2	0	2	0	2	0
DW-206	2	0	2	1	2	0	2	0	2	0	2	0
DW-207	2	0	2	0	2	0	2	0	2	0	2	0
DW-208	1	0	1	0	1	0	1	0	1	0	1	0

TABLE 2-5
SBC RI GROUND-WATER DRINKING WATER STANDARD EXCEEDENCES (Continued)

Station	Diss As		Diss Cd		Diss Cu		Diss Fe		Diss Pb		Diss Zn	
	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex
DW-210	1	0	1	0	1	0	1	0	1	0	1	0
DW-212	2	0	2	0	2	0	2	0	2	0	2	0
DW-215	1	0	1	0	1	0	1	0	1	0	1	0
DW-218	1	0	1	0	1	0	1	0	1	0	1	0
DW-229	1	0	1	0	1	0	1	0	1	0	1	0
DW-230	2	0	2	0	2	0	2	0	2	0	2	0
DW-301	1	0	1	0	1	0	1	0	1	0	1	0
DW-304	1	0	1	0	1	0	1	0	1	0	1	0
DW-309	1	0	1	0	1	0	1	0	1	0	1	0
DW-311	1	0	1	0	1	0	1	0	1	0	1	0
DW-312	2	0	2	0	2	0	2	0	2	0	2	0
DW-314	1	0	1	0	1	0	1	0	1	0	1	0
DW-318	2	0	2	0	2	0	2	0	2	0	2	0
DW-319	1	0	1	0	1	0	1	0	1	0	1	0
DW-321	1	0	1	0	1	0	1	0	1	0	1	0
DW-327	1	0	1	0	1	0	1	0	1	0	1	0
DW-328	1	0	1	0	1	0	1	0	1	0	1	0
DW-329	1	0	1	0	1	0	1	0	1	0	1	0
DW-336	1	0	1	0	1	0	1	0	1	0	1	0
DW-337	1	0	1	0	1	0	1	0	1	0	1	0
DW-340	2	0	2	0	2	0	2	0	2	0	2	0
DW-341	1	0	1	0	1	0	1	0	1	0	1	0
DW-401	2	0	2	0	2	0	2	2	2	2	2	0
DW-403	2	0	2	0	2	0	2	0	2	0	2	0
DW-404	2	0	2	0	2	0	2	0	2	0	2	0
DW-405	4	0	4	0	4	0	4	0	4	0	4	0
DW-408	1	0	1	0	1	0	1	0	1	0	1	0
DW-411	1	0	1	0	1	0	1	0	1	0	1	0
DW-412	1	0	1	0	1	0	1	0	1	0	1	0
DW-414	1	0	1	1	1	0	1	0	1	0	1	0
DW-415	1	0	1	0	1	0	1	0	1	0	1	0
DW-416	1	0	1	0	1	0	1	0	1	0	1	0
DW-501	1	0	1	0	1	0	1	0	1	0	1	0
DW-502	1	0	1	0	1	0	1	0	1	0	1	0
DW-504	1	0	1	0	1	0	1	0	1	0	1	0
DW-505	1	0	1	0	1	0	1	0	1	0	1	0

TABLE 2-5
SBC RI GROUND-WATER DRINKING WATER STANDARD EXCEEDENCES (Continued)

Station	Diss As		Diss Cd		Diss Cu		Diss Fe		Diss Pb		Diss Zn	
	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex	N	Ex
GS-01	4	0	4	0	4	0	4	0	4	0	4	0
GS-02	2	0	2	0	2	0	2	0	2	0	2	0
GS-03	4	0	4	0	4	0	4	0	4	0	4	0
GS-04	4	0	4	0	4	0	4	0	4	0	4	0
GS-05	3	0	3	0	3	0	3	0	3	0	3	0
GS-06	3	0	3	0	3	0	3	0	3	0	3	0
GS-07	2	0	2	0	2	0	2	0	2	0	2	0
GS-08	2	0	2	0	2	0	2	0	2	0	2	0
GS-09	2	0	2	2	2	2	2	2	2	0	2	2
GS-10A	2	0	2	2	2	2	2	2	2	0	2	2
GS-10B	2	0	2	2	2	2	2	2	2	1	2	2
GS-11	2	0	2	2	2	2	2	2	2	0	2	2
GS-12	2	0	2	0	2	0	2	0	2	0	2	0
GS 13A	2	0	2	2	2	0	2	2	2	2	2	2
GS-13B	2	0	2	1	2	0	2	2	2	0	2	0
GS-14	3	0	3	0	3	0	3	0	3	0	3	0
GS-15A	2	0	2	0	2	0	2	0	2	0	2	0
GS-15B	2	0	2	0	2	0	2	0	2	0	2	0
STP-GW	0	0	0	0	3	0	3	0	0	0	3	3
TS-01	4	0	4	0	4	0	4	0	4	0	4	0
TS-10	7	0	7	1	7	1	7	2	7	0	7	0
TS-11	8	8	8	1	8	0	8	0	8	1	8	0
TS-14	3	0	3	3	3	0	3	3	3	1	3	2
TS-15	3	0	3	2	3	0	3	2	3	0	3	0
TS-16	2	0	2	2	2	2	2	1	2	2	2	2
WSP-1	3	0	3	0	3	0	3	0	3	0	3	0
WSP-2A	2	0	2	0	2	0	2	0	2	0	2	0
WSP-2B	2	2	2	0	2	0	2	2	2	0	2	0
WSP-3A	3	0	3	0	3	0	3	0	3	0	3	0
WSP-3B	2	0	2	0	2	0	2	0	2	0	2	0
WSP-4	3	0	3	0	3	0	3	0	3	0	3	0
WSP-5	1	0	1	0	1	0	1	0	1	0	1	0

Station locations shown on Map 4-1.

Notes: N = Number of measurements.
EX = Number of Exceedences.

2.2.4.1 Surface Water

Arsenic

Arsenic in the Silver Bow Creek/Upper Clark Fork River system appeared to be introduced and transported in a solid state (as a particulate). The data supporting this conclusion are discussed in the Surface Water and Point Source Investigation Report (Appendix A). Because arsenic appeared in a solid state in this system, the potential toxicity and potential for bioaccumulation were reduced. Dissolved arsenic has greater toxicity and bioaccumulation potential (USEPA 1980b). Total arsenic concentrations remained low most of the time, rising to peaks only during high flows such as occurred during storm runoff events.

The arsenic was probably transported as an adsorbed species on precipitated iron oxides (See Appendix A). During periods of low flow, arsenic was deposited into the bedload sediment of Silver Bow Creek (available for re-entrainment during high flow), deposited into the sediments of the Warm Springs Ponds, or transferred to the upper Clark Fork River. During low flow, approximately 40% of the arsenic entering the Warm Springs Ponds exited the ponds via the permitted discharge (See Appendix A). During high flow events (high enough to bypass the Warm Springs Ponds - See Appendix C), arsenic and other suspended sediment elements from Silver Bow Creek entered the upper Clark Fork River where they become part of the

bedload sediment and suspended sediment. This occurred once during the RI period.

Cadmium

Because cadmium appeared to be transported in Silver Bow Creek in the dissolved state (See Appendix A), the potential for toxicity to aquatic life was high. Cadmium chemistry is similar to zinc chemistry, with both elements forming precipitates at pH's of 8-9 (depending on the anionic forms found in solution).

Cadmium in Silver Bow Creek appeared to remain mostly in solution until the creek entered the Warm Springs Ponds. The ponds appeared to remove approximately 75 to 80% of the cadmium during high- and low-flow events (See Appendix A). The cadmium that exited the Warm Springs Ponds entered the Clark Fork River, while that precipitated in the ponds was deposited on the bottom of the ponds along with the other solid sediments that settled out of Silver Bow Creek water (See Appendix C).

Copper

Copper entered the Silver Bow Creek system as a dissolved species and as a solid species. Upstream of the Colorado Tailings the water chemistry allowed the dissolved copper species to remain dissolved. However, below the Colorado Tailings the water chemistry

changed to favor copper adsorption, precipitation, or coprecipitation. A percentage of copper remained in the dissolved fraction (defined as the copper that passes a 0.45 μ filter) throughout the creek, but in the lower reaches this copper was likely to be ionic complexes that passed the filter (See Appendix A).

The copper load carried by Silver Bow Creek met the following fates:

- Deposition as a precipitate, coprecipitate, or adsorbate in the bedload sediment of the creek where it is available for re-entrainment during high flows;
- Deposition as a precipitate, co-precipitate, or adsorbate into the sediments of the Warm Springs Ponds;
- Flowing through or around the ponds as part of the solid or dissolved fraction not removed by the ponds and entering the upper Clark Fork River.

Iron

Iron entered Silver Bow Creek as a dissolved constituent in ground-water discharges and in both solid and dissolved forms from tributary discharges (See Appendix A). Because of the chemical characteristics of the water receiving this ground-water inflow, the dissolved iron immediately began to form solids. The slow rate of the reactions which form the iron solids leaves some iron in the dissolved state. During low flows, some of the iron precipitated and settled out of the water column and became part of the bedload sediment, which was re-entrained during high flows. The remaining iron

solids remained in the water column as suspended sediment and were transported downstream in this form (See Appendix A).

During high-flow events the Warm Springs Ponds removed approximately 43% of the total iron that entered the ponds. During low flow, this percentage rose to approximately 78% (See Appendix C). The iron that passed through or around the ponds (in a bypass event) entered the upper Clark Fork River.

Lead

Because lead compounds generally are of such low solubilities, they are transported in aquatic systems as part of the suspended and bedload sediments. This was the case in Silver Bow Creek (See Appendix A). Flow was the major factor affecting the transport of suspended and bedload sediments in Silver Bow Creek.

During low flows, suspended sediments tend to drop out of the water column but are re-entrained during high flows. On Silver Bow Creek, this phenomenon was observed in the loads of lead removed by the Warm Springs Ponds--less lead reached the ponds during low flow. During the high-flow events measured during the SBC RI, 6.2 lbs/day of lead were removed by the ponds, and during the low-flow periods, 1.5 lbs were removed by the ponds. The removal efficiencies (calculated as lbs removed versus lbs entering) of the ponds during low flow and high flow were calculated as 92.2 and 81.3% respectively. This insignificant difference in flow-related removal efficiencies

for lead entering the Warm Springs Ponds (as compared to other solid constituents) was attributed to the heavier weight of the lead salts in suspension (See Appendix A).

Because the insoluble lead salts in suspension are heavier than other suspended sediment constituents, the ultimate fate of most of the lead in Silver Bow Creek was the bottom of the Warm Springs Ponds. That small percentage of lead that passed through the ponds or bypassed the ponds during a high-flow event, was distributed by the fluvial processes of the Clark Fork River.

Zinc

Zinc was introduced into Silver Bow Creek primarily as a dissolved species. However, the chemistry of Silver Bow Creek favored zinc adsorption by suspended sediments. Zinc adsorption was favored in Silver Bow Creek until the Warm Springs Ponds were reached, where the pH was high enough to favor zinc precipitation.

This phenomena was reflected in the average percentage of zinc in the dissolved state decreasing from approximately 83% at the MSD to 18% at the outfall from the Warm Springs Ponds. The adsorbed zinc was transported as part of the suspended and bedload sediments. The suspended sediments settled out of the water column in low-gradient areas during low-flow conditions to become part of the bedload. During high-flow conditions these sediments were re-entrained (See Appendix A).

2.2.4.2 Ground Water

Contaminants found in the ground-water systems sampled during the RI were transported in the dissolved state. Because dissolved contaminants can be adsorbed by particulate matter, the concentrations of contaminants may decrease as a function of distance from the source. However, the RI data collected were insufficient to precisely describe this function, as this process is dependent on several physical and chemical characteristics of the water and aquifer materials that were not measured.

Ground-water inputs of arsenic and lead to Silver Bow Creek appeared to be insignificant. However, ground-water inputs of cadmium, copper, iron, and zinc appeared to be significant sources of these contaminants to Silver Bow Creek.

2.2.5 Potential For Bioaccumulation

Potential bioaccumulation of contaminants was evaluated in four investigations of the SBC RI: Fish Tissue, Waterfowl, Agriculture, and Algae. Only circumstantial evidence was collected that suggested algae were accumulating metals from Silver Bow Creek and the Warm Springs Ponds during the SBC RI period.

2.2.5.1 Arsenic

Freshwater aquatic life show a relatively low potential for the accumulation of arsenic. The USEPA (1985c) reported a range from 1.2 to 17 for bioconcentration factors (tissue concentration divided by ambient water concentration) for tested freshwater aquatic species. The USEPA (1981) suggests that arsenic has a moderate potential for bioaccumulation in mammals and birds. Bioconcentration factors (BF) for fish tissue tested from the Warm Springs ponds confirm these findings with a range of zero to ten.

Liver and muscle tissue from Warm Springs Ponds waterfowl exhibited arsenic concentrations no greater than that found in domestic waterfowl by the USDA (See Appendix E, part 4), which indicates that waterfowl using the Warm springs Ponds did not evidence arsenic bioconcentration. The SBC RI Agriculture Investigation concluded that arsenic in soil was elevated above expected background at some of the sites sampled and that the plants on these sites were bioaccumulating arsenic (See Appendix D, Part 3).

2.2.5.2 Cadmium

Cadmium bioaccumulation in the tissue of aquatic organisms is highly variable, ranging from a BF of 3 for brook trout to a BF of 12,400 for the mosquitofish (USEPA 1985d). In fish, cadmium has low BF's for muscle tissue, with large BF's for other organs (USEPA

1985d). The USEPA (1981) suggests that cadmium has a high potential for bioconcentration in mammals, birds, and fish.

The SBC RI data indicate that the fish in the Warm Springs ponds are bioconcentrating cadmium, with cadmium being found at higher concentrations in the liver than in the muscle (See Appendix E, Part 3). Observed salmonid BF's for cadmium in different tissues are from 3 to 540 (USEPA 1980c).

Cadmium concentrations in Warm Springs Ponds waterfowl (muscle and liver) tissue tested during the SBC RI appeared higher than domestic waterfowl tissues tested by the USDA, indicating the waterfowl are bioconcentrating cadmium. Warm Springs Ponds waterfowl were differentially concentrating cadmium; the higher values occurred in the livers (See Appendix E, Part 4).

Newman and Gavlak (1984) have noted that total soil cadmium concentrations are not well correlated with plant concentrations for those species evaluated. Several of the more contaminated soil sites sampled for the SBC RI Agriculture Investigation showed elevated levels of cadmium in plant tissues, indicating that for the species tested bioaccumulation was occurring (See Appendix D, Part 3).

2.2.5.3 Copper

Aquatic organisms have a wide range of BF's for copper. Bluegills have been shown to have a BF of zero, while the algae Chlorella regularis has been shown to bioconcentrate copper up to 2,000 times the ambient concentration (USEPA 1985e). The USEPA (1981) suggests that copper has a high potential for selective tissue bioaccumulation in mammals, birds, and fish.

Fish tested from the Warm Springs Ponds appeared to be bioaccumulating copper in their livers and muscle, but only the liver concentrations appeared to be elevated above concentrations of copper found in tissues of fish from relatively uncontaminated water (See Appendix E, Part 3).

Muscle and liver tissue from waterfowl collected at the Warm Springs Ponds did not appear to be concentrating copper at rates greater than domestic waterfowl tested by the USDA. BF's for the tested waterfowl were not calculated, as the ambient exposure concentration was not known (See Appendix E, Part 4).

Plant species tested during the SBC RI at specific sites showed copper levels in plant material that could be toxic to domestic livestock, indicating that bioaccumulation was occurring (See Appendix D, Part 3).

2.2.5.4 Iron

Because iron is a required element for many organisms, processes for the physiological control of iron distribution within organisms have developed. These processes significantly reduce the potential for bioaccumulation. Because iron has such a low potential for bioaccumulation in mammals, birds, and fish, the USEPA (1981) did not even list the element for consideration for biological monitoring of toxic trace elements. Iron was not tested in the tissue of fish or waterfowl collected from the SBC RI site. Several plant species tested during the SBC RI showed iron levels above expected geochemical background levels, indicating certain plant species growing in contaminated soil were accumulating iron. However, none of these concentrations exceeded guidelines for iron concentrations in forage (See Appendix D, Part 3).

2.2.5.5 Lead

The USEPA (1981) suggests that lead has a high potential for bioaccumulation in mammals, birds, and fish. BF's calculated for lead in four species of freshwater invertebrates ranged from 499 to 1700. BF's calculated for lead in brook trout and bluegills were 42 and 45 respectively. Lead concentrations were not determined for the fish tissues tested for the SBC RI, as total lead values in the ambient water were not often above the aquatic life criteria and lead was postulated to occur primarily in the non-toxic solid phase due to the chemical characteristics of Silver Bow Creek and

the Warm Springs Ponds. Lead concentrations were not determined in waterfowl tissue tested for the SBC RI for the same reasons as presented for the fish tissues and also because the waterfowl were collected with lead shot.

Lead has a low potential for bioaccumulation by plants in the above-ground portions of the plant, and moderate potential for bioaccumulation or association with the plant roots. SBC RI data generally confirmed this, with few samples showing higher than geochemically expected concentrations (See Appendix D, Part 3).

2.2.5.6 Zinc

Because zinc is an essential micronutrient, the USEPA (1981) did not list zinc as being potentially bioaccumulated by mammals, birds, or fish. Zinc BF's for two species of freshwater fish were reported by the USEPA (1980b) to be 51 and 432, and for two species of freshwater invertebrates, to be 107 and 1130.

SBC RI fish tissue data reflect the low potential for bioaccumulation, with BF's calculated as 20 and 185 for muscle and liver tissue respectively (See Appendix E, Part 3). Waterfowl tissues did not show zinc concentrations greater than the zinc concentrations reported by the U.S. Department of Agriculture (USDA) for domestic waterfowl (See Appendix E, Part 4).

Zinc has a high potential for accumulation by plants due to its mobility. This was confirmed by the data from the SBC RI Agricultural Investigation which suggested zinc as one of the major contaminants being incorporated into plant tissues on contaminated soil (See Appendix D, Part 3).

2.2.6 Potential For Environmental Transformation

Because arsenic and lead in Silver Bow Creek were introduced and transported primarily in the adsorbed or solid state, they were relatively non-toxic for aquatic life. The only significant transformations would be the desorption of the arsenic from particulates or the dissolution of lead particulates. The primary factor controlling these processes in Silver Bow Creek was pH (See Appendix A). Because the pH of Silver Bow Creek was relatively neutral to alkaline downgradient (See Appendix A), the potential for environmental transformations to the more toxic dissolved forms was small (arsenic adsorption and lead precipitation are favored at alkaline pH's). However, natural or man-caused perturbations to the existing condition (as measured by the SBC RI) which cause the pH to fall significantly may affect the forms of arsenic and lead found in Silver Bow Creek and the resulting toxicity to aquatic life.

Because the cadmium in Silver Bow Creek was transported in a dissolved form, the most significant transformation that could take place is the precipitation of cadmium to a solid phase. This

transformation would significantly reduce cadmium toxicity. Cadmium precipitation occurs at hydrogen ion concentrations that are occasionally reached in Silver Bow Creek and are often reached in the Warm Springs Ponds (See Appendices A and C), so the potential for environmental transformation of cadmium is high.

Transformation of dissolved copper to solid phases of copper occurred in Silver Bow Creek during the RI (See Appendix A). Significant changes in pH, iron chemistry, or flow regime would have a considerable effect on the location and completeness of this transformation.

Transformation of introduced dissolved iron to solid iron precipitates occurred in Silver Bow Creek. Factors controlling this transformation were pH, Eh, dissolved CO_2, and the concentration and form of associated sulfur species. Changes in any of these factors would affect the timing, location, and efficiency of this transformation.

Environmental transformation of zinc occurred in Silver Bow Creek during the RI, with the introduced dissolved zinc becoming part of the suspended and bedload sediment due to adsorption. Changes to the pH and concentrations of adsorbates (such as iron hydroxides) would affect the timing and location of zinc adsorption (See Appendix A). Dissolved zinc was further removed from the water column during the SBC RI by precipitation in the Warm Springs Ponds.

2.2.7 Potential For Further Off-Site Migration

Contaminants that are precipitated as a solid in either Silver Bow Creek or the Warm Springs Ponds could be released offsite by high flow events that bypass the ponds (for contaminants precipitated in the creek), which happens at frequent intervals (See Appendix A), or by the Probable Maximum Flood that destroys the integrity of pond structures, causing a wash-out of pond sediments (Hydrometrics 1983b). The pond inflow structure was designed to withstand the 100-year flood (Hydrometrics 1983b) but would not withstand the Probable Maximum Flood. Sediments entrained in the upper Clark Fork River will settle out as a result of natural fluvial processes. No natural or man-made barriers occur to remove these sediments until the Milltown Dam is reached, thus allowing them to be transported beyond the Kohrs Bridge (the end point of the SBC site).

The contaminants that exit the ponds (approximately 50% of the total load entering the ponds during the SBC RI: see Appendix C) also have the potential for further offsite migration, as no physical or chemical changes were observed in the upper Clark Fork River that would prevent the contaminants from being transported past the Kohrs Bridge.

2.2.8 Effects to Beneficial Use

Other than direct consumption, the other major potential uses of the surface water and ground water of Silver Bow Creek and the upper Clark Fork River are irrigation and stock watering. Tables 2-6 and 2-7 present the number of times SBC RI samples exceeded Montana irrigation and stock-watering criteria (MDHES 1986) at each station for total arsenic, cadmium, copper, iron, lead, and zinc; also shown are the total number of measurements of these parameters. The greatest number of ground-water sites exhibiting exceedences occurred in the upper MSD area or were associated with the Ramsay Flats lysimeters. The surface-water sites with most of the exceedences also occurred in the upper part of the SBC drainage. Site locations for stations indicated on these tables are shown on Maps 3-1 and 4-1.

TABLE 2-6
SURFACE WATER IRRIGATION AND STOCK WATERING
CRITERIA EXCEEDENCES DURING THE SBC RI

Station	Total As[a]			Total Cd[b]			Total Cu[c]			Total Fe[d]			Total Pb[e]			Total Zn [f]		
	N	IR	SW	N	IR	SW	N	IR	SW	N	IR	SW	N	IR	SW	N	IR	SW
*PS-0A	2	0	0	2	0	0	2	0	0	2	0		2	0	2	2	0	0
*PS-01	1	1	1	1	1	1	1	0	1	1	1		1	0	1	1	1	0
*PS-02	2	1	1	2	1	1	2	1	1	2	1		2	0	1	2	1	0
*PS-03	1	0	0	1	0	0	1	0	0	1	0		1	0	1	1	0	0
*PS-04	8	0	0	8	0	0	9	0	2	8	0		8	0	2	9	0	0
*PS-07	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
*PS-08	16	0	0	16	0	0	20	1	1	18	0		18	0	0	25	1	0
PS-08A	3	0	0	3	0	0	3	0	0	3	0		3	0	0	3	0	0
PS-10	13	0	0	13	0	0	13	0	0	13	0		13	0	0	13	0	0
PS-11	15	0	0	15	0	0	15	0	0	15	0		15	0	0	15	0	0
PS-11A	17	0	0	17	0	0	17	0	0	17	0		17	0	0	17	0	0
PS-12	16	0	0	16	0	0	16	0	0	16	0		16	0	0	16	0	0
*PS-13	11	0	0	11	0	0	11	0	0	11	0		11	0	1	11	0	0
*SS-02	6	0	0	6	2	2	6	1	3	6	0		6	0	1	6	1	0
*SS-03	15	1	1	15	5	5	16	1	11	15	1		15	0	2	16	5	0
*SS-04	16	0	0	16	0	0	17	0	0	16	0		16	0	0	17	0	0
SS-05	14	0	0	14	0	0	14	0	0	14	0		14	0	0	14	0	0
SS-06	6	0	0	6	0	0	6	0	0	6	0		6	0	0	6	0	0
*SS-07	16	1	0	16	0	0	17	0	1	16	0		16	0	2	17	0	0
SS-08	14	0	0	14	0	0	14	0	0	14	0		14	0	0	14	0	0
SS-09	13	0	0	13	0	0	13	0	0	13	0		13	0	0	13	0	0
SS-10	7	0	0	7	0	0	7	0	1	7	0		7	0	0	7	0	0
SS-11	15	0	0	15	0	0	15	0	0	15	0		15	0	0	15	0	0
SS-12	14	0	0	14	1	1	14	1	2	14	0		14	0	1	14	2	2
SS-13	15	0	0	15	0	0	15	0	0	15	0		15	0	0	15	0	0
SS-14	14	0	0	14	0	0	14	0	0	14	0		14	0	1	14	0	0
SS-15	15	0	0	15	0	0	15	0	0	15	0		15	0	0	15	0	0
SS-16	15	0	0	15	0	0	15	0	0	15	0		15	0	3	15	0	0
SS-17	11	0	0	11	0	0	11	0	0	11	0		11	0	0	11	0	0
SS-18	14	1	0	14	0	0	14	0	0	14	0		14	0	0	14	0	0
SS-19	12	0	0	12	0	0	12	0	0	12	0		12	0	0	12	0	0
*SS-20	15	0	0	15	1	0	15	0	0	15	0		15	0	0	15	0	0
SS-21	17	0	0	17	0	0	17	0	0	17	0		17	0	0	17	0	0
SS-22	18	0	0	18	0	0	18	0	0	18	0		18	0	0	18	0	0

TABLE 2-6
SURFACE WATER IRRIGATION AND STOCK WATERING
CRITERIA EXCEEDENCES DURING THE SBC RI (Continued)

	Total As(a)			Total Cd(b)			Total Cu(c)			Total Fe(d)			Total Pb(e)			Total Zn (f)		
Station	N	IR	SW	N	IR	SW	N	IR	SW	N	IR	SW	N	IR	SW	N	IR	SW
SS-23	15	0	0	15	0	0	15	0	0	15	1		15	0	1	15	0	0
SS-24	15	0	0	15	0	0	15	0	0	15	0		15	0	1	15	0	0
SS-25	15	1	0	15	0	0	15	0	0	15	0		15	0	0	15	0	0
SS-26																		
SS-27	8	0	0	8	0	0	8	0	0	8	0		8	0	0	8	0	0
SS-27A	9	2	0	9	0	0	9	0	0	9	5		9	0	0	9	0	0
SS-28	13	0	0	13	0	0	13	0	0	13	0		13	0	0	13	0	0
SS-29	15	0	0	15	0	0	15	0	0	15	0		15	0	0	15	0	0
SS-30	2	0	0	2	0	0	2	0	0	2	0		2	0	0	2	0	0
SS-31	2	0	0	2	0	0	2	0	0	2	0		2	0	0	2	0	0
SS-32	2	0	0	2	0	0	2	0	0	2	0		2	0	0	2	0	0
SS-33	2	0	0	2	0	0	2	0	0	2	0		2	0	0	2	0	0
SS-34	2	0	0	2	0	0	2	0	0	2	0		2	0	0	2	0	0
SS-35	2	0	0	2	0	0	2	0	0	2	0		2	0	0	2	0	0
SS-36	2	0	0	2	0	0	2	0	0	2	0		2	0	0	2	0	0

Note: Sample sites are shown on Map 3-1.

N = Number of measurements
IR = Number of irrigation criteria exceedences
SW = Number of stock watering criteria exceedences

* Includes duplicates and/or storm run-off sampling.
** Does not include samples collected during bioassay test.

(a) As: IR Criteria = 0.10 mg/L, SW Criteria = 0.20 mg/L (MDHES 1986).

(b) Cd: IR Criteria = 0.05 mg/L, SW Criteria = 0.05 mg/L (MDHES 1986).

(c) Cu: IR Criteria = 5.0 mg/L, SW Criteria = 0.50 mg/L (MDHES 1986).

(d) Fe: IR Criteria = 20.0 mg/L, (MDHES 1986).

(e) Pb: IR Criteria = 10.0 mg/L, SW Criteria = 0.10 mg/L (MDHES 1986).

(f) Zn: IR Criteria = 10.0 mg/L, SW Criteria = 25.0 mg/L (MDHES 1986).

TABLE 2-7
GROUND-WATER IRRIGATION AND STOCK-WATERING CRITERIA EXCEEDENCES
DURING THE SBC RI

Station	N[a]	Diss As[b]		Diss Cd[c]		Diss Cu[d]		Diss Fe[e]		Diss Pb[f]		Diss Zn[g]	
		IR	SW	IR	SW	IR	SW	IR	SW	IR	SW	IR	SW
DW-101	2	0	0	2	2	2	2	2		0	0	2	2
DW-102	3	0	0	1	1	0	0	0		0	0	0	0
DW-103	2	0	0	0	0	0	0	0		0	0	0	0
DW-105	4	0	0	4	4	0	2	2		0	0	4	4
DW-106	2	0	0	0	0	0	0	0		0	0	0	0
DW-107	3	0	0	0	0	0	0	0		0	0	0	0
DW-108	1	0	0	1	1	0	0	0		0	0	1	1
DW-109	3	2	0	0	0	0	0	3		0	0	1	0
DW-110	3	1	1	0	0	0	0	3		0	0	0	0
DW-111	2	0	0	0	0	0	0	0		0	0	0	0
DW-112	4	0	0	0	0	0	0	0		0	0	0	0
DW-114	3	0	0	0	0	0	0	0		0	0	0	0
DW-115	3	0	0	0	0	0	0	0		0	0	0	0
DW-116	4	0	0	0	0	0	0	0		0	0	0	0
DW-117	1	0	0	0	0	0	0	0		0	0	0	0
DW-118	3	0	0	0	0	0	0	0		0	0	0	0
DW-119	4	1	0	0	0	0	0	4		0	0	0	0
DW-121	4	0	0	0	0	0	0	0		0	0	0	0
DW-122	1	0	0	0	0	0	0	0		0	0	0	0
DW-123	1	0	0	0	0	0	0	0		0	0	0	0
DW-124	2	0	0	0	0	0	0	0		0	0	0	0
DW-125	1	0	0	0	0	0	0	0		0	0	0	0
DW-128	2	0	0	0	0	0	0	0		0	0	0	0
DW-129	2	0	0	0	0	0	0	0		0	0	0	0
DW-130	3	0	0	0	0	0	0	0		0	0	0	0
DW-131	3	0	0	0	0	0	0	0		0	0	0	0
DW-132	1	0	0	1	1	0	1	0		0	0	1	1
DW-133	2	0	0	0	0	0	0	0		0	0	0	0
DW-134	2	0	0	2	2	0	0	0		0	0	2	2
DW-135	2	0	0	0	0	0	0	0		0	0	0	0
DW-136	1	0	0	1	1	1	1	0		0	1	1	1
DW-137	2	0	0	2	2	2	2	0		0	2	2	2
DW-202	1	0	0	0	0	0	0	0		0	0	0	0
DW-203	2	0	0	0	0	0	0	0		0	0	0	0
DW-204	2	0	0	0	0	0	0	0		0	0	0	0
DW-206	2	0	0	0	0	0	0	0		0	0	0	0
DW-207	2	0	0	0	0	0	0	0		0	0	0	0
DW-208	1	0	0	0	0	0	0	0		0	0	0	0

TABLE 2-7
GROUND-WATER IRRIGATION AND STOCK-WATERING CRITERIA EXCEEDENCES
DURING THE SBC RI (Continued)

Station	N[a]	Diss As[b]		Diss Cd[c]		Diss Cu[d]		Diss Fe[e]		Diss Pb[f]		Diss Zn[g]	
		IR	SW	IR	SW	IR	SW	IR	SW	IR	SW	IR	SW
DW-209	1	0	0	0	0	0	0	0		0	0	0	0
DW-210	1	0	0	0	0	0	0	0		0	0	0	0
DW-212	2	0	0	0	0	0	0	0		0	0	0	0
DW-215	1	0	0	0	0	0	0	0		0	0	0	0
DW-218	1	0	0	0	0	0	0	0		0	0	0	0
DW-229	1	0	0	0	0	0	0	0		0	0	0	0
DW-230	2	0	0	0	0	0	0	0		0	0	0	0
DW-301	1	0	0	0	0	0	0	0		0	0	0	0
DW-304	1	0	0	0	0	0	0	0		0	0	0	0
DW-309	1	0	0	0	0	0	0	0		0	0	0	0
DW-311	1	0	0	0	0	0	0	0		0	0	0	0
DW-312	2	0	0	0	0	0	0	0		0	0	0	0
DW-314	1	0	0	0	0	0	0	0		0	0	0	0
DW-318	2	0	0	0	0	0	0	0		0	0	0	0
DW-319	1	0	0	0	0	0	0	0		0	0	0	0
DW-321	1	0	0	0	0	0	0	0		0	0	0	0
DW-327	1	0	0	0	0	0	0	0		0	0	0	0
DW-328	1	0	0	0	0	0	0	0		0	0	0	0
DW-329	1	0	0	0	0	0	0	0		0	0	0	0
DW-336	1	0	0	0	0	0	0	0		0	0	0	0
DW-337	1	0	0	0	0	0	0	0		0	0	0	0
DW-340	2	0	0	0	0	0	0	2		0	0	0	0
DW-341	1	0	0	0	0	0	0	0		0	0	0	0
DW-401	2	0	0	0	0	0	0	2		0	0	0	0
DW-403	2	0	0	0	0	0	0	0		0	0	0	0
DW-404	2	0	0	0	0	0	0	0		0	0	0	0
DW-405	4	0	0	0	0	0	0	0		0	0	0	0
DW-408	1	0	0	0	0	0	0	0		0	0	0	0
DW-411	1	0	0	0	0	0	0	0		0	0	0	0
DW-412	1	0	0	0	0	0	0	0		0	0	0	0
DW-414	1	0	0	0	0	0	0	0		0	0	0	0
DW-415	1	0	0	0	0	0	0	0		0	0	0	0
DW-416	1	0	0	0	0	0	0	0		0	0	0	0
DW-501	1	0	0	0	0	0	0	0		0	0	0	0
DW-502	1	0	0	0	0	0	0	0		0	0	0	0
DW-504	1	0	0	0	0	0	0	0		0	0	0	0
DW-505	1	0	0	0	0	0	0	0		0	0	0	0

TABLE 2-7
GROUND-WATER IRRIGATION AND STOCK-WATERING CRITERIA EXCEEDENCES
DURING THE SBC RI (Continued)

Station	N[a]	Diss As[b]		Diss Cd[c]		Diss Cu[d]		Diss Fe[e]		Diss Pb[f]		Diss Zn[g]	
		IR	SW	IR	SW	IR	SW	IR	SW	IR	SW	IR	SW
GS-01	4	0	0	0	0	0	0	0		0	0	0	0
GS-02	2	0	0	0	0	0	0	0		0	0	0	0
GS-03	4	0	0	0	0	0	0	0		0	0	0	0
GS-04	4	0	0	0	0	0	0	0		0	0	0	0
GS-05	3	0	0	0	0	0	0	0		0	0	0	0
GS-06	3	0	0	0	0	0	0	1		0	0	0	0
GS-07	2	0	0	2	2	1	2	0		0	0	2	1
GS-08	2	0	0	0	0	0	0	0		0	0	0	0
GS-09	2	0	0	1	1	0	2	0		0	0	2	0
GS-10A	2	0	0	2	2	0	2	0		0	0	2	1
GS-10B	2	0	0	2	2	2	2	1		0	1	2	2
GS-11	2	0	0	2	2	0	2	1		0	0	2	1
GS-12	2	0	0	0	0	0	0	0		0	0	0	0
GS-13A	2	0	0	0	0	0	2	0		0	2	1	0
GS-13B	2	0	0	0	0	0	0	0		0	0	0	0
GS-14	3	0	0	0	0	0	0	0		0	0	0	0
GS-15A	2	0	0	0	0	0	0	0		0	0	0	0
GS-15B	2	0	0	0	0	0	0	0		0	0	0	0
STP-GW	3[h]	-	-	-	-	0	1	0		-	-	3	2
TS-01	4	0	0	0	0	0	0	0		0	0	0	0
TS-10	7	0	0	0	0	0	0	0		0	0	0	0
TS-11	8	7	3	0	0	0	0	0		0	1	0	0
TS-14	3	0	0	0	0	0	0	0		0	1	1	0
TS-15	3	0	0	0	0	0	0	0		0	0	0	0
TS-16	2	0	0	2	2	2	2	0		0	2	2	2
WSP-1	3	0	0	0	0	0	0	0		0	0	0	0
WSP-2A	2	0	0	0	0	0	0	0		0	0	0	0
WSP-2B	2	2	1	0	0	0	0	2		0	0	0	0
WSP-3A	3	0	0	0	0	0	0	0		0	0	0	0
WSP-3B	2	0	0	0	0	0	0	0		0	0	0	0
WSP-4	3	0	0	0	0	0	0	0		0	0	0	0
WSP-5	2	0	0	0	0	0	0	0		0	0	0	0

Note: Station locations are shown on Map 4-1.

(a) Number of measurements for each parameter.
(b) As: IR Criteria = 0.10 mg/L, SW Criteria = 0.20 mg/L (MDHES 1986).
(c) Cd: IR Criteria = 0.05 mg/L, SW Criteria = 0.050 mg/L (MDHES 1986).
(d) Cu: IR Criteria = 5.0 mg/L, SW Criteria = 0.50 mg/L (MDHES 1986).
(e) Fe: IR Criteria = 20.0 mg/L (MDHES 1986).
(f) Pb: IR Criteria = 10.0 mg/L, SW Criteria = 0.10 mg/L (MDHES 1986).
(g) Zn: IR Criteria = 10.0 mg/L, SW Criteria = 25.0 mg/L (MDHES 1986).

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3.0 SURFACE WATER INVESTIGATION

This chapter summarizes key technical information presented in the Surface Water and Point Source Investigation Report, Appendix A. Conclusions are based only on data collected during this RI (December 1984-August 1985) and not on historic data. Historic data were evaluated and compared to RI data as appropriate.

The nine-month study period had drier-than-normal weather, as shown in precipitation records and flows in Silver Bow Creek (See Table 3-1). The effects of the dry year were fewer surface runoff events and fewer high flow events that cause sediment erosion and transport. These events, while more frequent in normal years, were quantified during this RI and can be used to predict effects in normal or wet years. The lower flows permitted an opportunity to study ground-water inflows to Silver Bow Creek. Temporal trends in flow data allowed the segregation of data into high- and low-flow regimes, which allowed more detailed analysis of the major mechanisms at work in Silver Bow Creek.

3.1 OBJECTIVES

Specific objectives of the Surface Water and Point Source Investigation were described in the SBC RI Work Plan (MultiTech and Stiller and Associates 1984a):

TABLE 3-1
PRECIPITATION DATA FROM BUTTE, MONTANA
(in inches)

MONTH	AVERAGE[a] PRECIPITATION	RI STUDY PERIOD PRECIPITATION[b]	DEPARTURE FROM AVERAGE INCHES	DEPARTURE FROM AVERAGE PERCENT(%)
November 1984	.49	.62	+.13	+27
December	.48	.26	-.22	-46
January 1985	.42	.17	-.25	-60
February	.44	.34	-.10	-23
March	.65	.69	+.04	+6
April	.90	.18	-.72	-80
May	1.74	1.66	-.08	-5
June	2.42	1.22	-1.20	-50
July	1.20	.33	-.87	-73
August	1.03	1.52	+.49	+48
TOTAL	9.77	TOTAL 6.99	TOTAL -2.78	-28

Note:

(a) Averages for the period 1931 to 1960 (NOAA, 1971)

(b) NOAA 1985

- Determine the spatial and temporal variations in surface-water quality and quantity;
- Determine the most affected stream reaches and the sources or mechanisms within them causing water quality degradation;
- Determine how stream-water quality changes during major precipitation runoff events; and
- Determine how stream water quality changes in response to ground-water discharges.

3.2 INVESTIGATION METHODS

Examination of the spatial and temporal variation of the surface water quality and quantity essentially described the severity and extent of the surface water contamination. It also lead to the formation of metals transport hypotheses that allowed the identification of sources and improved understanding of toxic effects. This information will assist in selecting appropriate remedial actions. The study of water quality during major precipitation events was particularly important for the identification of sources of metal contamination, such as mine waste dumps and mill tailings, that reach the stream by a surface route. Another important route for metals contamination was ground-water inflow, and a major effort in the surface water study was the identification of ground-water inflow locations. The data collected in the Surface Water and Point Source Investigation help determine the relative importance of the surface- and ground-water pathways, and thereby aid in the identification of remedial alternatives.

The Surface Water and Point Source Investigation primarily studied the following metals: copper, zinc, iron, lead, arsenic, and cadmium. Other parameters were measured to aid in the identification of contaminant sources, elucidate the chemistry of the metals, understand the role of algae in metals transport, and evaluate toxicity of the metals. The investigation report describes methods of measuring those analytes and presents the results and interpretations of those measurements.

The study area of the SBC RI Surface Water and Point Source Investigation extended from the Weed Concentrator outfall in Butte to near Garrison Junction in the Deer Lodge Valley (Map 3-1). The central focus of the investigation was Silver Bow Creek and its downstream extension, the Clark Fork River. Tributary streams were not investigated other than to assess their impact on Silver Bow Creek and upper Clark Fork River. Point sources (shown on Map 3-1) were evaluated for their contribution of contaminant load to the creek, but upstream investigations were not performed. Those areas showing the most contribution were within the boundaries of the Butte Add-On study area, an area proposed for CERCLA site status as an addition to the SBC RI site but not included within the original site boundaries.

Field work extended from November of 1984 to September of 1985. The bulk of the field work consisted of monthly (November 1984 - January 1985 and July - August 1985) or semimonthly (February - June 1985) sampling of Silver Bow Creek, the upper Clark Fork

LEGEND

- ○ SURFACE WATER SAMPLE SITE
- ● PERMANENT GAGE SITE AND SURFACE WATER SAMPLE SITE
- ▲ POINT SOURCE SAMPLE SITE
- □ SEEPAGE SURFACE WATER SAMPLE SITE

SCALE 1" = 2.27 MILES

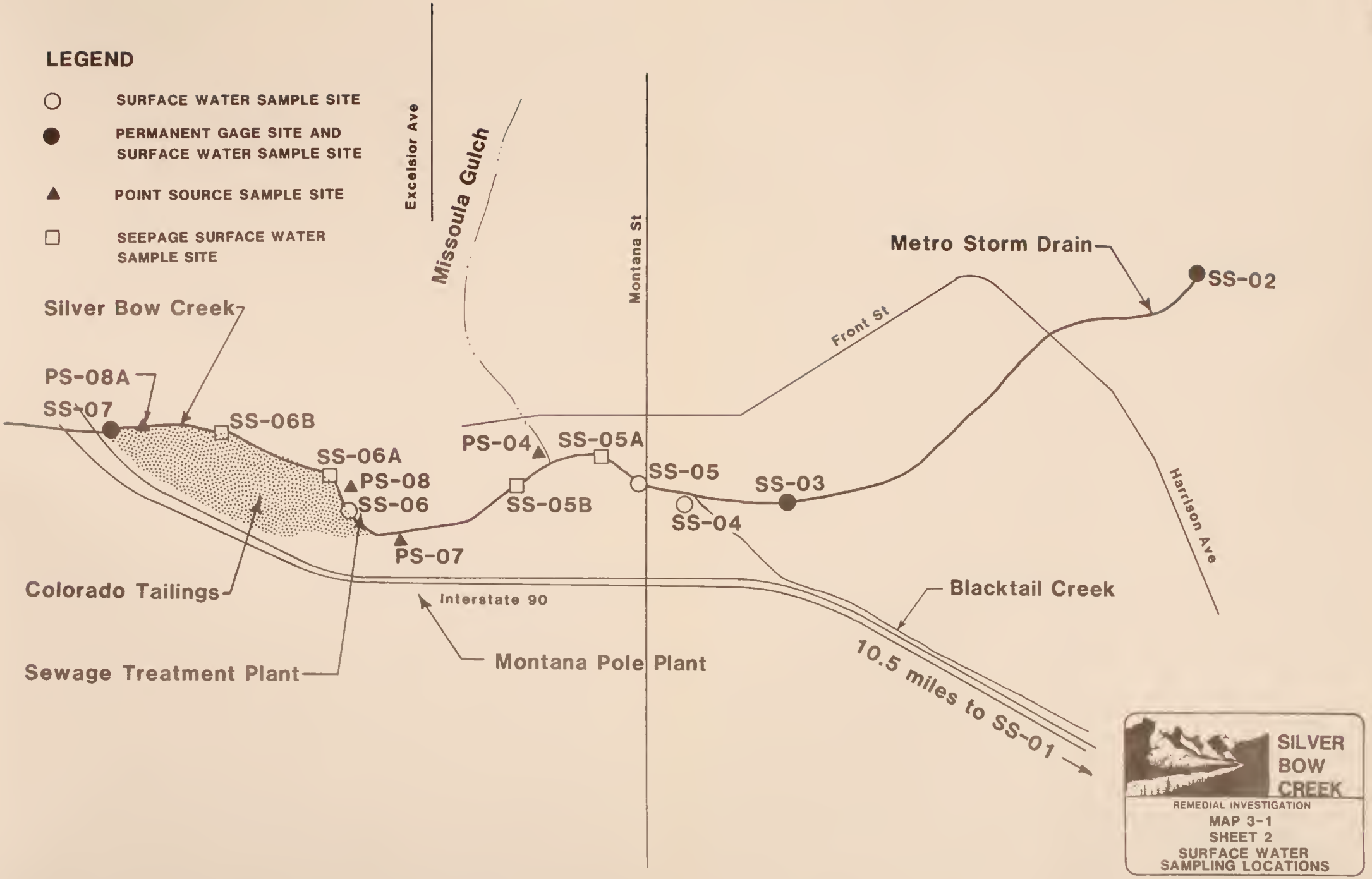
SEE MAP 3-1 SHEET 2

CONTINENTAL DIVIDE
HIGHLAND MOUNTAINS
YANKEE DOODLE POND
BUTTE
BLACKTAIL CR.
SUMMIT VALLEY
BASIN CR.
LITTLE BASIN CR.
BERKELEY PIT
WEST CONCENTRATOR
CLARK TAILINGS
COLORADO TAILINGS
ROCKER
NISSLER
BROWNS GULCH
SAND CR.
SILVER BOW
RAMSAY
RAMSAT FLATS TAILINGS
DAWSON
MILES CROSSING
SILVERBOW CREEK CANYON
SILVER BOW CREEK
CRACKERVILLE
FAIRMONT HOT SPRINGS
GERMAN GULCH
FLINT CR.
OPPORTUNITY
MILL CR.
WILLOW CR.
WARM SPRINGS PONDS
MILL-WILLOW BYPASS
LOST CR.
WARM SPRINGS CR.
DEERLODGE VALLY
COTTONWOOD CR.
PETERSEN CR.
CARIBOU CR.
DRY COTTONWOOD CR.
CLARK FORK RIVER
DEER LODGE
DEMPSEY
GALEN
RACETRACK CR.
TAYLOR CR.
POWELL CR.
DEMPSEY CR.
MODESTY CR.
FLINTCREEK RANGE

SS-08 SS-09 SS-10 SS-10A SS-10B SS-11A SS-11 PS-10 PS-11 SS-12 SS-13 SS-13A SS-14 SS-14A SS-14B SS-15 SS-16 SS-16A SS-16B SS-16C SS-17 SS-17A SS-17B SS-19 SS-28 SS-29 PS-12 SS-30 SS-31 SS-32

SILVER BOW CREEK

REMEDIAL INVESTIGATION
MAP 3-1
SHEET 1
SURFACE WATER
SAMPLING LOCATIONS


LEGEND
SURFACE WATER SAMPLE SITE
PERMANENT GAGE SITE AND SURFACE WATER SAMPLE SITE
POINT SOURCE SAMPLE SITE
SEEPAGE SURFACE WATER SAMPLE SITE
Excelsior Ave
Missoula Gulch
Montana St
Metro Storm Drain
SS-02
Front St
Silver Bow Creek
PS-08A
SS-07
SS-06B
SS-06A
PS-08
SS-06
PS-07
PS-04
SS-05A
SS-05B
SS-05
SS-04
SS-03
Harrison Ave
Colorado Tailings
Interstate 90
Blacktail Creek
Sewage Treatment Plant
Montana Pole Plant
10.5 miles to SS-01
SILVER BOW CREEK
REMEDIAL INVESTIGATION
MAP 3-1
SHEET 2
SURFACE WATER SAMPLING LOCATIONS

River, point sources, and tributaries. Field data collected included flow, pH, conductivity, and temperature. Laboratory data included the major cations (occasionally); the major anions; total suspended solids (TSS); dissolved copper, iron, and zinc; and total copper, iron, zinc, arsenic, lead, and cadmium. Selected samples from specific sites also were analyzed for ortho-phosphate, total phosphate, fluoride, PCP, PCB, cyanide, oil and grease, and total organic carbon.

Data analysis was performed to identify contaminant sources, transport mechanisms or pathways, and hydrologic fate of the contaminants. Investigation methods, results, and recommendations are detailed in Appendix A.

3.3 INVESTIGATION FINDINGS

3.3.1 Sources

Contaminants enter the Silver Bow Creek system through two major pathways: surface runoff and ground-water inflow. An additional pathway is the re-entrainment of previously deposited bank and channel materials. Distinguishing these pathways is important so that appropriate remedial alternatives can be developed during the feasibility study. The surface-water data identifies major contaminant sources throughout the Silver Bow Creek study area. The most dramatic increases in contaminants occur in and near Butte, and

sources generally become less important as the creek approaches the Warm Springs Ponds.

Table 3-2 summarizes contaminant loads contributed by each point source during the entire RI period. The amount of contaminants contributed by each source varies considerably with flow conditions. While it appears that the MSD and Missoula Gulch contribute small loads when compared to Browns Gulch, their relative impact in terms of water quality degradation may be greater. Two factors must be carefully evaluated together in planning remedial options: (1) total material loadings to the creek, and (2) relative impact of each point source on water quality in Silver Bow Creek.

Table 3-2 shows the MSD and Missoula Gulch are the primary point sources causing degradation of Silver Bow Creek. At higher flows, Browns Gulch becomes an additional degradational point source of iron, arsenic, and lead; the actual source is likely the Ramsay Flats tailings deposit. When the STP is pumping ground water, it also degrades Silver Bow Creek with zinc and cadmium.

Non-point source contributions are presented in Table 3-3 for comparison with Table 3-2. The ground-water inputs shown are extrapolated from low-flow conditions; high-flow inputs are assumed to be similar. The comparison shows that ground water entering the creek between SS-05 (Montana Street) and SS-07 (Colorado Tailings) is a major source of copper, zinc, arsenic, cadmium, and sulfate.

TABLE 3-2
FLOWS AND LOADS CONTRIBUTED BY POINT SOURCE TO SILVER BOW CREEK OVER THE ENTIRE RI PERIOD (DEC. 1984 - AUG. 1985).

	Metro Storm Drain (SS-03)	Missoula Gulch (PS-04)	Butte Sewage Treatment Plant (PS-08)		Silver Lake Discharge (PS-11)	Browns Gulch (SS-12)	German Gulch (SS-15)
			Entire RI	Normal[a]			
Flow ($10^6 ft^3$)	12.7	2.6	228.4	221.4	324.5	70.4	258.2
Sulfate (lbs.)	478000[b]	17000[b]	804000	679000	168000	153000	149000
Cu (lbs.)	551[b]	94[b]	681	539	268	341	232
Zn (lbs.)	6664[b]	415[b]	11473[b]	1313	229	729	211
Fe (lbs.)	4411[b]	1908[b]	2429	2399	1660	8603[b]	2114
As (lbs.)	12.9[b]	5.3[b]	58.1	54.8	3.0	132.0[b]	46.
Pb (lbs.)	13.9[b]	23.9[b]	43.4	41.9	83.0	549.1[b]	16.
Cd (lbs.)	25.5[b]	1.7[b]	24.4[b]	0.4	0.0	0.3	0.0

Notes:

(a) During normal operations, excludes ground-water pumping episodes (corrected to entire RI period).

(b) Degrades Silver Bow Creek Water Quality at confluence.

TABLE 3-3
FLOWS AND LOADS CONTRIBUTED BY NON-POINT SOURCES
TO SILVER BOW CREEK OVER THE ENTIRE RI PERIOD

	GROUND WATER			BANK OR CHANNEL SEDIMENT ENTRAINMENT[a]	
	SS-02 to SS-03 (MSD)	SS-05 to SS-06 (GW1)	SS-06 to SS-07 (GW2)	SS-07 to SS-10 (SED1)	SS-13 to SS-16 (SED2)
Flow ($10^6 ft^3$)	9.1	30.2	26.9	--	--
Sulfate (lbs.)	376000	401000	246000	--	--
Cu (lbs.)	412	2551	2452	1645	1561
Zn (lbs.)	5870	5428	12188	1764	1855
Fe (lbs.)	2570	0	5036	10829	9240
As (lbs.)	7.1	63.4	139.2	154	154
Pb (lbs.)	3.1	11.7	16.6	224	315
Cd (lbs.)	15.4	17.0	27.9	--	--

Note:

(a) Probably channel sediment re-entrainment deposited from another source.

Areas of ground-water input were identified using flow data. Previously deposited channel or bank sediments appear to be mobilized during higher flows (see Table 3-3), though flows were probably not high enough to cause significant bank erosion during this RI. Though the data are not conclusive, bank entrainment and/or channel sediment re-entrainment appear to be major "sources" of copper, iron, arsenic, and lead to Silver Bow Creek. Channel sediment re-entrainment should not be considered a source, while bank erosion should be, and distinguishing the two is not possible with RI data.

Table 3-4 summarizes and ranks the contaminant sources outlined above during this remedial investigation of Silver Bow Creek. The ranking in Table 3-4 is based on total loads delivered to Silver Bow Creek during the RI, not on water quality degradation effects. Those effects must be evaluated independently. Tables 3-2, 3-3, and 3-4 may be used to extrapolate the 1985 RI data to normal or wet years.

3.3.2 Transport

Analysis of the RI data (Pearson's Correlation Analysis, Principle component analysis, and geochemical modelius) indicate that most metal contaminants (iron, copper, lead, and arsenic) are transported as solid phases, either as mineral sediments, precipitates, or adsorbates. Zinc and cadmium are transported primarily as dissolved constituents, although some are bound as adsorbates.

TABLE 3-4
RANKING OF CONTAMINANT LOADING SOURCES TO SILVER BOW CREEK USING TOTAL LOADS DELIVERED DURING THE ENTIRE RI PERIOD[a]

	1	2	3	4	5
Cu	GW1	GW2	SED1[b]	SED2[b]	PS-08[c]
Zn	GW2	PS-08[c]	SS-03	GW1	SED2[b]
Fe	SED1[b]	SED2[b]	SS-12	GW2	SS-03
As	SED1[b]	SED2[b]	GW2	SS-12	GW1
Pb	SS-12	SED2[b]	SED1[b]	PS-11	PS-08[d]
Cd	GW2	SS-03	PS-08[c]	GW1	--
Sulfate	PS-08[d]	SS-03	GW1	GW2	PS-11

NOTES:

(a) Key:

GW1 = Groundwater inflow between SS-05 and SS-06
GW2 = Groundwater inflow between SS-06 and SS-07
SS-03 = Metro Storm Drain
PS-04 = Missoula Gulch
PS-08 = Butte Sewage Treatment Plant
PS-11 = Silver Lake Discharge
SS-12 = Browns Gulch
SED1[d] = Sediment Entrainment between SS-07 and SS-10
SED2[d] = Sediment Entrainment between SS-13 and SS-16

(b) Probably channel sediment re-entrainment, deposited from another source.

(c) PS-08 (STP) during entire study, including ground-water pumping.

(d) PS-08 (STP) during normal operations, not including ground-water pumping.

Conditions in Silver Bow Creek favor the precipitation of iron along the entire creek. Precipitation of copper is favored downstream of station SS-07, and zinc should not precipitate anywhere except very near the Warm Springs Ponds. Iron precipitation is slow (kinetically controlled), hence more is found in a dissolved state than predicted by equilibrium calculations. Copper and arsenic adsorb to, and may be coprecipitated with, iron. Lead is generally not soluble and is present primarily as mineral sediment. Zinc and cadmium are present primarily in dissolved forms. Zinc is more likely to adsorb than cadmium under conditions found in Silver Bow Creek.

Contaminant transport is most significant during the relatively few high-flow events, where solid phases are mobilized. Bedload sediment transport, though not measured, is probably significant in the movement of solid-phase contaminants in Silver Bow Creek.

3.3.3 Fate

Contaminants delivered by Silver Bow Creek have two possible fates: the Warm Springs Treatment Ponds and the Clark Fork River. Table 3-5 presents total amounts of contaminants that remained in the Warm Springs Ponds or that were supplied to the Clark Fork River during the RI. Using the entire study period integrates contaminant loads for the relatively infrequent high-flow events and the normal low-flow conditions, and accounts for the lower pond system efficiencies in winter. As noted earlier, 1985 was a low-water year,

TABLE 3-5
FATE OF CONTAMINANTS DELIVERED BY SILVER BOW CREEK DURING THE RI PERIOD[a]

	Amount Remaining in Warm Springs Ponds		Amount Released by Warm Springs Ponds to the Clark Fork River[b]	
	(lbs)	% of input	(lbs)	% of input
Sulfate	-232,111	-3.3	7,265,778	103.3
Cu	8,531	65.0	4,594	35.0
Zn	22,428	60.4	14,704	39.6
Fe	52,586	59.9	35,204	40.1
As	674	36.3	1,183	63.7
Pb	681	72.8	254	27.2
Cd	93	87.0	14	13.0

Notes:

(a) Includes only the period December 26 to August 27, 1985 (Runs 2-15). Inlet (SS-19) was frozen from December 3, 1984 through March 11, 1985 sampling runs. Data from SS-16 was used for these periods.

(b) Does not include Pond System bypass of early June 1985.

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and an average year would probably increase the amount of contaminants delivered to both receptors. Because the ponds are less efficient during higher flows, a relatively greater amount would be delivered to the Clark Fork River. The table shows the pond system removed approximately 87% of the cadmium, 73% of the lead, 65% of the copper, 60% of the iron and zinc, and 36% of the arsenic loads delivered by Silver Bow Creek during the RI period. The unremoved contaminants then flow into the upper Clark Fork River, where their ultimate fate is determined primarily by impoundments (dams) and natural fluvial processes. The implication is that, except for low flows during the summer, approximately 40% of the contaminants

delivered to the Warm Springs Ponds are not removed and continue into the Clark Fork River.

3.3.4 Severity and Extent of Contamination

This RI found definite evidence of surface-water contamination in Silver Bow Creek and found some evidence of water quality problems on the upper Clark Fork River. This contamination indicates a severely degraded resource and may pose hazards to human health, as well as to aquatic life and the environment.

The contamination is both severe and extensive, as shown in Tables 2-4 and 2-5. These tables shows the MSD (SS-02 and SS-03) to be the most severely contaminated part of the study area. Concentrations of total cadmium and zinc regularly exceed drinking water standards, and other contaminants are less frequently above this standard. Missoula Gulch is also regularly above the standard for lead, and infrequently for other metals.

Aquatic Life Criteria (1-hour) for copper and zinc are regularly exceeded at most sites along Silver Bow Creek, indicating the contamination extends downstream to the Warm Springs Ponds. This is a conservative comparison, since USEPA recommends using "acid-soluble" concentrations and only dissolved concentrations were used in this study, thereby underestimating the acid-soluble metals.

During the storm event of May 29, 1985 all the measured total metals (arsenic, cadmium, copper, iron, lead, and zinc) exceeded Federal drinking water standards at most of the Silver Bow Creek stations measured. This event demonstrates both that the severity and the extent of surface water contamination greatly increases during storm runoff conditions.

Another parameter of concern on Silver Bow Creek is pentachlorophenol (PCP), which was detected at SS-06 just below the Montana Pole and Treatment site. The concentration once exceeded the drinking water lifetime health advisory for adults of 0.22 mg/L. The Montana Pole and Treatment site is currently being handled by a USEPA emergency response team.

3.4 RECOMMENDATIONS

This section recommends additional data collection that may be necessary for the completion of the feasibility study on Silver Bow Creek. Justification for each of the data needs also is provided.

Additional data is needed in four areas:

- Identification Of Ultimate Sources Of Contamination. To determine the ultimate source of metals found in Silver Bow Creek, contaminant sources outside the current RI study area must be measured and compared. This sampling should include mines and tailings deposits in Butte and the surrounding areas. Inputs to the storm sewers need to be identified and quantified.

- Effect of High Flows and Storm Runoff On Floodplain Tailings Deposits. Data collected to date are inconclusive about the effects of high flow and storm events on fluvially deposited tailings which form some of the Silver Bow Creek floodplain. The effect of very high flows on stream bank stability and erosion needs a more detailed evaluation as a possible source of metals to Silver Bow Creek during those events. Storm events cause erosion and transport of surface deposits to Silver Bow Creek. This surface runoff may be a source of contamination and should be quantified to determine its significance. A sampling episode is necessary during one or more high flow and storm events, preferably around the Ramsay Flats and Colorado Tailings areas. This episode should involve sampling above, along, and below the tailings deposits, as well as runoff from the surface. A means to measure bank erosion also should be employed.

- Continued Monitoring of Flow on Silver Bow Creek. During the RI, continuous flow data were obtained from four sites along Silver Bow Creek. These data, in conjunction with the USGS gage data below Colorado Tailings, provided the means of assessing the temporal variation in flow. Because the flow regime measured was below normal, the usefulness of these data for estimating the design and operation of possible remedial alternatives is limited. The four continuous recording gages established during the Silver Bow Creek RI should be reactivated at least during the spring, summer, and fall seasons of another year. The data then collected can be used to extrapolate RI data to normal or wet years.

- Additional Sampling on the Upper Clark Fork River. The very limited sampling along this portion of the study area was insufficient to provide a meaningful characterization. If this area is important to the overall RI/FS goals, additional data are necessary to characterize bank sediment entrainment and ground-water inflow as sources of contaminants to the Clark Fork River.

DRAFT

4.0 HYDROGEOLOGIC INVESTIGATION

This chapter summarizes information from the Ground Water and Tailings Investigation Report, Appendix B.

The Silver Bow Creek RI was conducted during an optimum year in which to evaluate ground-water impacts to Silver Bow Creek. Below-average snowpack and precipitation in 1985 (See Appendix A) resulted in near base-flow conditions throughout most of the study. Because of this, several chronic sources of metals contamination to Silver Bow Creek could be identified with relative accuracy.

4.1 OBJECTIVES

Phase I of the hydrogeologic investigation (January - July 1985) of the SBC RI site was planned to assess the general sources, extent and severity, and relationships with surface waters of ground-water contamination in aquifers and tailings deposits adjacent to the Silver Bow Creek and the upper Clark Fork River.

Objectives of the Phase I field investigation were as follows:

- Determine general ground-water recharge/discharge conditions;
- Determine general rates and directions of shallow ground-water movement;
- Quantify spatial and temporal hydrochemistry of shallow ground-water to delineate between natural and contaminated waters;

- Quantify hydrologic relationships between shallow ground-water and surface-water systems;
- Confirm areal extent and depth of tailings and other wastes along Silver Bow Creek and the upper Clark Fork River;
- Quantify physical and chemical characteristics of tailings and related waste materials;
- Quantify unsaturated, vertical fluid movement through tailings and its effect on solute concentrations; and
- Quantify temporal fluctuations of ground-water levels within saturated tailings and the resultant effects of solute concentrations.

4.2 INVESTIGATION METHODS

The Phase I investigation was accomplished in several tasks:

- Completion of inventory of domestic, industrial, and monitoring wells in the study area;
- Acquisition, review, and evaluation of historic ground-water data;
- Sampling of tailings deposits to determine their heterogeneity and characteristics;
- Tailings vadose (undisturbed) zone well installation and sampling;
- Installation and sampling of additional monitoring wells in selected areas; and
- Surveying new well elevations and locations.

As a result of the Phase I ground-water data and early surface-water data, specific geographic areas were selected for more detailed hydrogeologic investigation during a Phase II study. The data

justifying the Phase II study were presented and discussed in a Preliminary Investigation Memorandum (Stiller and Associates 1985).

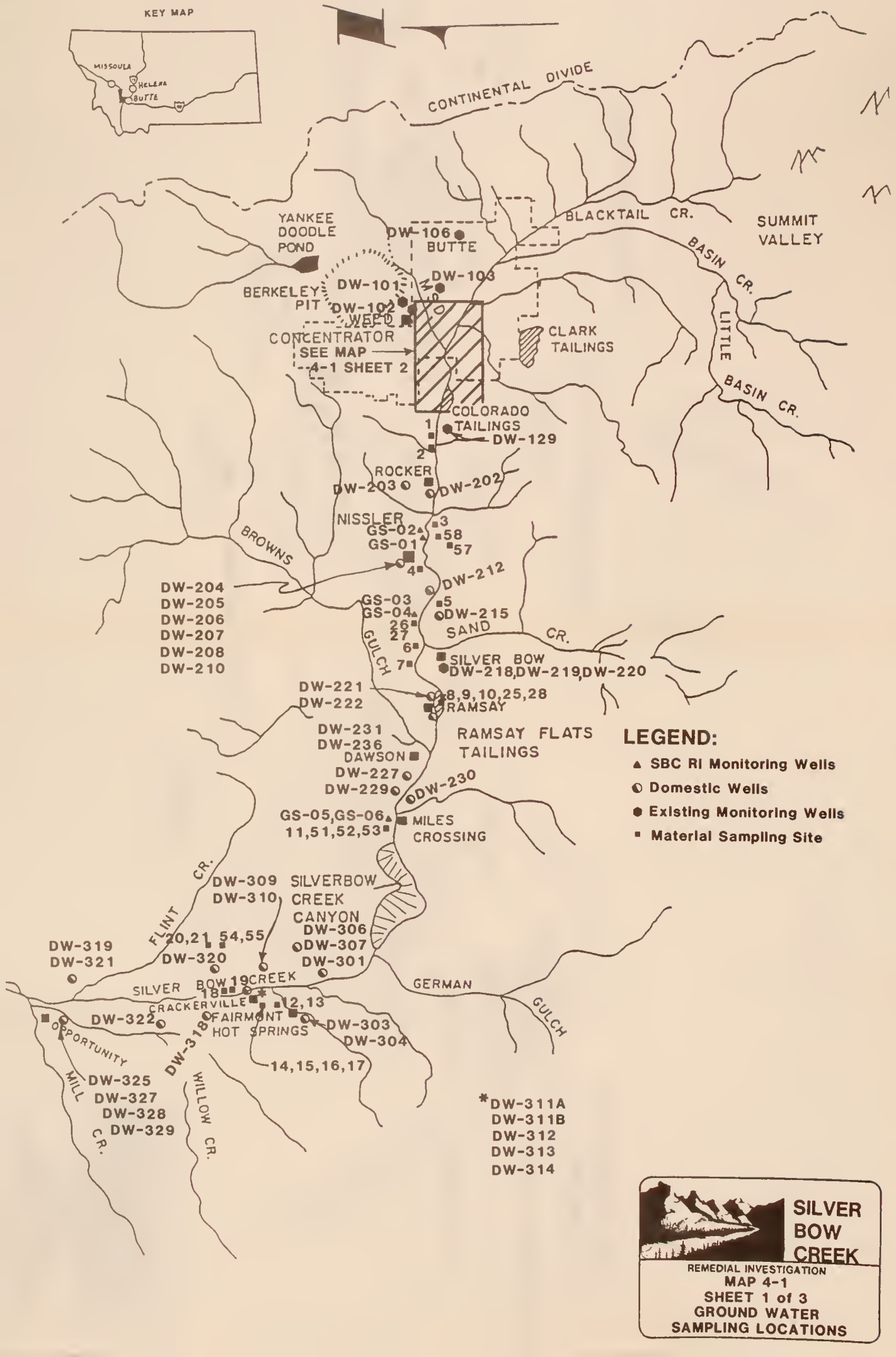
Selected for additional study were the area around the Metro Storm Drain, lower Missoula Gulch and upper Silver Bow Creek, the arsenic treating plant at Rocker, and the Warm Springs Ponds area.

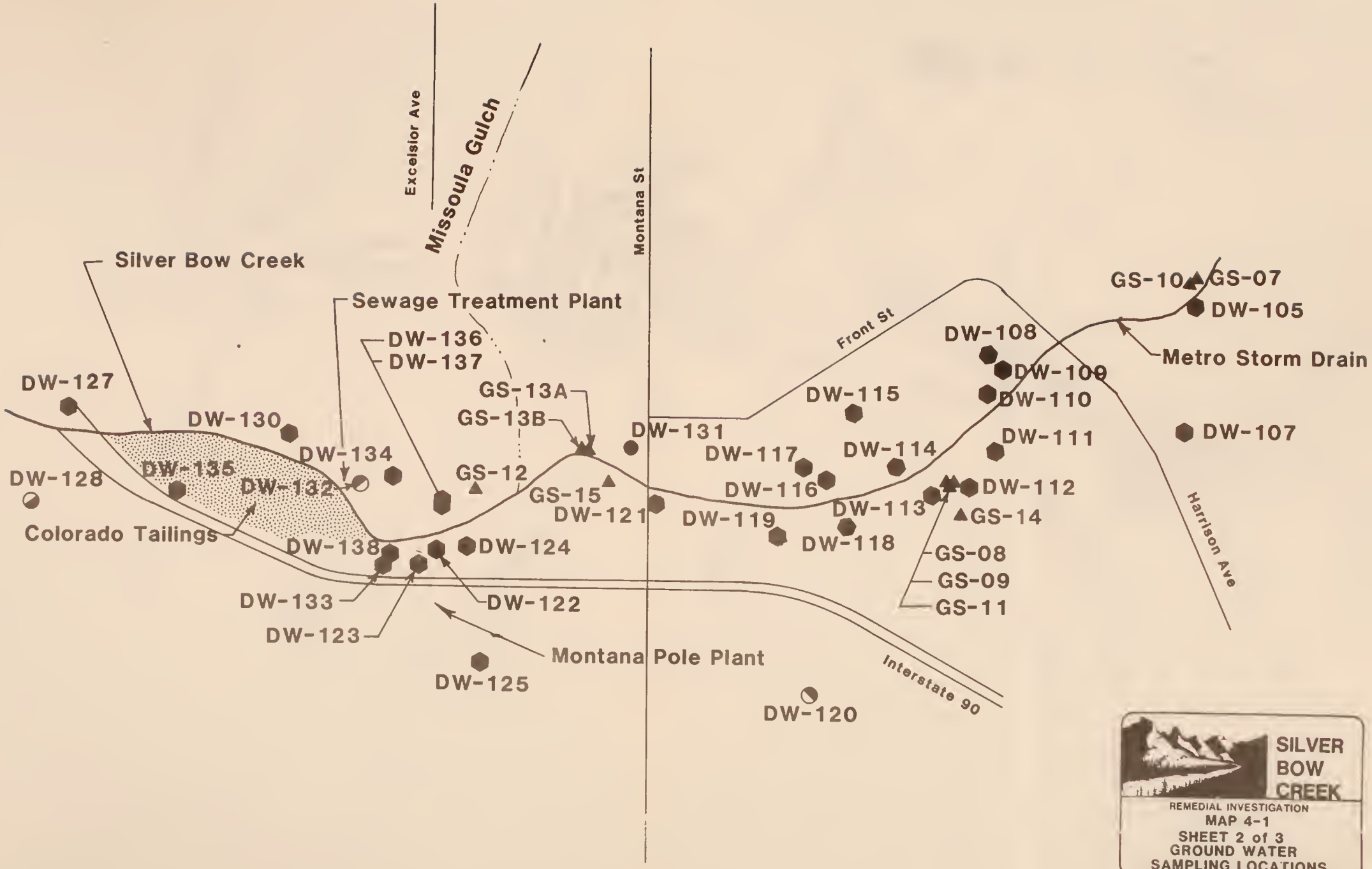
The major tasks of the Phase II ground-water investigation (December 1985 - January 1986) included installation, drilling, and sampling, of additional wells in the selected areas. Aquifer testing also was performed in selected areas. All new wells were surveyed to establish their location and elevation.

The resulting data were analyzed for the following information:

- The role of ground water in contributing to the contamination of surface water;
- The contamination of ground water in the study area;
- The interaction between ground water and tailings; and
- The reclamation potential of tailings deposits.

Investigation methods, results, and recommendations are presented in Appendix B. Map 4-1 shows the locations of the wells sampled during the SBC RI.


KEY MAP
MISSOULA
HELENA
BUTTE
CONTINENTAL DIVIDE
YANKEE DOODLE POND
DW-106
BUTTE
BLACKTAIL CR.
SUMMIT VALLEY
BASIN CR.
LITTLE BASIN CR.
BERKELEY PIT
DW-101
DW-102
DW-103
WEP
CONCENTRATOR
SEE MAP 4-1 SHEET 2
CLARK TAILINGS
COLORADO TAILINGS
DW-129
ROCKER
DW-203
DW-202
NISSLER
GS-02
GS-01
BROWNS GULCH
DW-204
DW-205
DW-206
DW-207
DW-208
DW-210
DW-212
GS-03
GS-04
DW-215
SAND CR.
SILVER BOW
DW-218,DW-219,DW-220
DW-221
DW-222
8,9,10,25,28
RAMSAY
RAMSAY FLATS TAILINGS
DW-231
DW-236
DAWSON
DW-227
DW-229
DW-230
GS-05,GS-06
11,51,52,53
MILES CROSSING
FLINT CR.
DW-309
DW-310
SILVERBOW CREEK CANYON
DW-306
DW-307
DW-301
DW-319
DW-321
20,21,54,55
DW-320
SILVER BOW CREEK
18
19
CRACKERVILLE
12,13
FAIRMONT HOT SPRINGS
DW-322
DW-318
DW-303
DW-304
GERMAN GULCH
OPPORTUNITY
MILL CR.
DW-325
DW-327
DW-328
DW-329
WILLOW CR.
14,15,16,17
*DW-311A
DW-311B
DW-312
DW-313
DW-314
LEGEND:
SBC RI Monitoring Wells
Domestic Wells
Existing Monitoring Wells
Material Sampling Site
SILVER BOW CREEK
REMEDIAL INVESTIGATION
MAP 4-1
SHEET 1 of 3
GROUND WATER
SAMPLING LOCATIONS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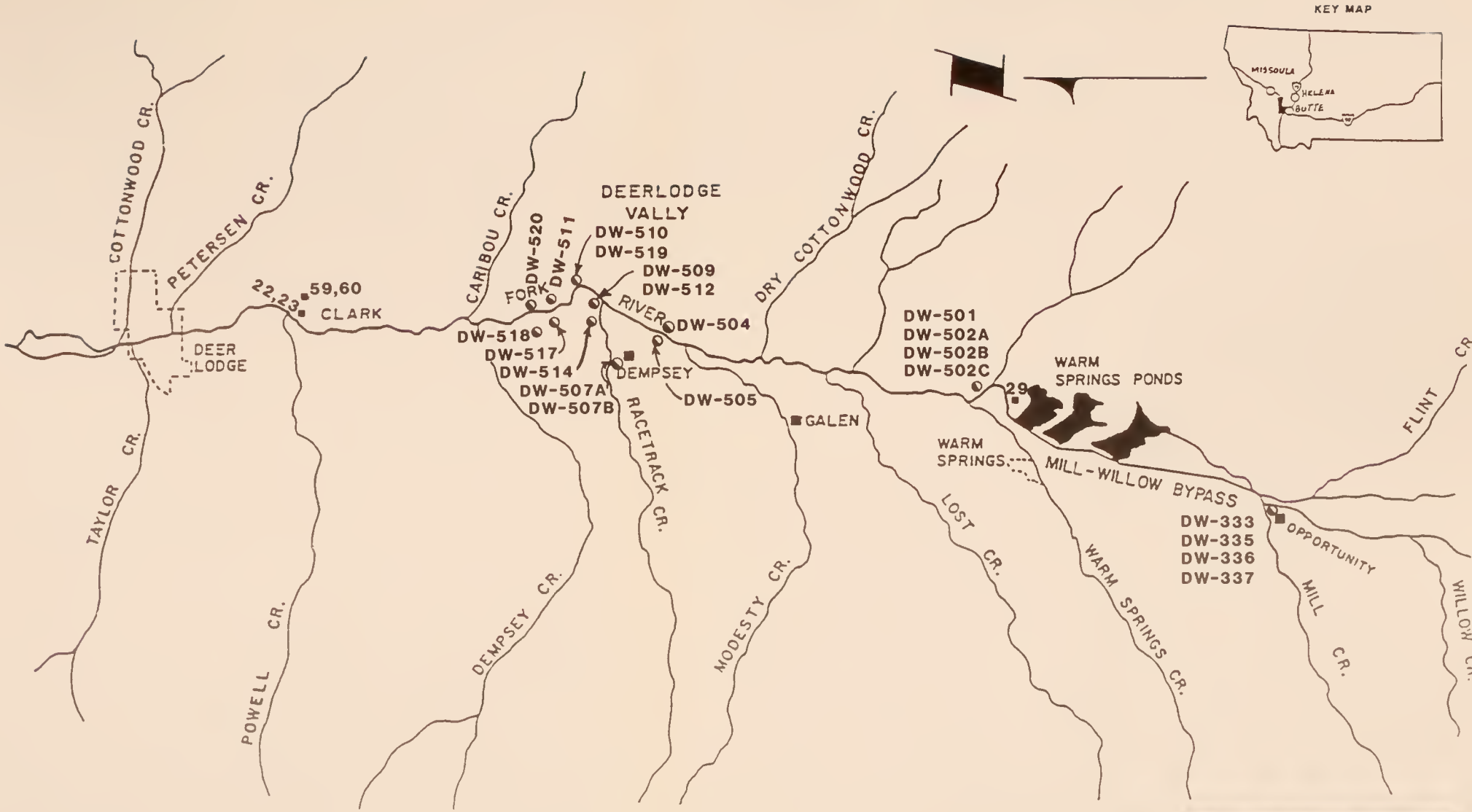
Montana St
Silver Bow Creek
Sewage Treatment Plant
DW-136
DW-137
DW-127
GS-13A
GS-13B
DW-130
DW-134
DW-131
DW-135
DW-132
GS-12
GS-15
DW-128
Colorado Tailings
DW-121
DW-138
DW-124
DW-133
DW-122
DW-123
Montana Pole Plant
DW-125
DW-120
Front St
DW-115
DW-108
DW-109
DW-110
DW-111
DW-117
DW-114
DW-116
DW-112
DW-113
GS-14
DW-119
DW-118
GS-08
GS-09
GS-11
GS-10
GS-07
DW-105
Metro Storm Drain
DW-107
Harrison Ave
Interstate 90
SILVER BOW CREEK
REMEDIAL INVESTIGATION
MAP 4-1
SHEET 2 of 3
GROUND WATER
SAMPLING LOCATIONS



SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 4-1

SHEET 3 of 3

GROUND WATER SAMPLING LOCATIONS

4.3 INVESTIGATION FINDINGS

4.3.1 Sources

Several potential sources of ground-water contamination were evaluated during the RI: Upper MSD (Parrot tailings), Weed Concentrator, STP vicinity (Butte Reduction Works), Colorado Tailings, Anaconda Pole Treatment Facility, Ramsay Flats, and fluvial tailings along Silver Bow Creek and the Clark Fork River. Table 4-1 summarizes the major findings concerning each of these potential sources evaluated during the RI.

The Surface-Water and Point Source Investigation (Appendix A) identified significant contaminated ground-water inflows in the MSD (SS-02 to SS-03) and between Montana Street and the western end of the Colorado Tailings (SS-05 to SS-07). Sources of contaminants to ground water in both the MSD and upper Silver Bow Creek areas should be considered higher priority problems than those in other areas: buried tailings in the upper MSD (Parrot), those in the STP vicinity (Butte Reduction Works), the Colorado Tailings, and possibly the Anaconda Pole Treatment Facility.

4.3.2 Transport

Several mechanisms may be responsible for mobilizing contaminants into surface and ground waters in the RI study area: (1) direct infiltration through tailings into underlying ground water;

TABLE 4-1

SUMMARY OF POTENTIAL GROUND-WATER CONTAMINATION SOURCES
FOUND DURING THE SBC RI

Potential Source	Type	RI Findings
Upper MSD (Parrot)	Buried Tailings	Subsurface material has extreme levels of metals. Ground water in, beneath, and downgradient from tailings is degraded.
Weed Concentrator	Discharge of Process Waters	Not evaluated, but a potential source, and may have amplified problems from buried tailings in MSD area.
STP Vicinity (Butte Reduction Works)	Buried Tailings	No site-specific tailings analysis. Ground water beneath and downgradient is severely degraded.
Colorado Tailings	Surface Tailings	Tailings have elevated metals and contaminated soils and ground water beneath (MBMG data). Metals concentrations in ground water increase to the northwest.
Anaconda Pole Treatment	Surface Soil Contamination	Surface soils have extreme levels of arsenic. Ground water was not characterized.
Ramsay Flats	Surface Tailings	Tailings contain up to 60 times background metals. Surface efflorescence contains extreme concentrations of metals (up to 15%). Underlying shallow ground water is degraded but, due to low gradients and transmissivity, does not move away from the site significantly.
Fluvial Tailings Along SBC and CFR	Surface Tailings	Tailings have elevated metals. Ground water may be locally affected but no significant contamination was found.

(2) ground-water flux through tailings deposits; (3) capillary action driving metallic salts to the surface and entrainment by surface runoff; and (4) direct erosion and entrainment of stream-side tailings. Other, less prominent, mechanisms include bank storage releases, artificial ground-water mounding, and geologic structure.

Infiltration studies performed on exposed tailings showed total, soluble, and acid extractable metals were greatly elevated. Partitioning of copper, zinc, cadmium, manganese, and occasionally iron into the soluble fraction at the low pH observed in the tailings indicates a significant potential for movement into ground water and surface water. Metal distribution in natural soils below the tailings indicates that these metals and arsenic have moved out of tailings, from five inches (lead) to more than 20 inches (cadmium, arsenic). The order of apparent decreasing mobility is arsenic > cadmium > zinc > copper > lead. Iron and manganese flux is uncertain due to their high background levels and limited enrichment; however, manganese appears similar to zinc in mobility.

Iron and manganese oxides have a tendency to adsorb or co-precipitate copper, arsenic, zinc, and (to a limited extent) cadmium from solution. If the pH + pe in the buried natural soils is above 12 to 15, these oxides would likely attenuate copper, zinc, and arsenic movement. However, no evidence indicates metal accumulation at the base of the tailings. Arsenic mobility is further affected by its valence state, which is determined by the redox potential. If the

pH + pe is 10 or lower in some buried soils, metal mobility would be enhanced. As a result, metals could be expected to move into ground water if significant recharge occurs.

Analysis of water flux in the vadose zone and pore water chemistry during the investigation indicates that only a limited amount of water movement occurred from tailings into the ground water. The period of study was drier than normal and preliminary computer modeling indicates that water flux would be substantial during more normal to above-normal precipitation periods.

Ground-water flux through buried tailings was not studied directly, but data collected around subsurface tailings was examined. The data demonstrate that tailings were releasing contaminants to ground water. Two controls on contaminant flux were postulated: lower Eh levels increasing sulfide stabilities, and low transmissivity within tailings deposits.

Accumulation of metal-rich, complex mixed-sulfate salts and hydrated oxide salts at tailings surfaces suggests a potential for entrainment of contaminants via surface runoff from areas of bare deposits. Entrainment of streamside tailings materials may occur during bankfull or flood stage events (see Appendix A, Surface Water and Point Source report).

The release of bank storage water during declining creek stage may also contribute to metal loading. Due to the lack of water use by

plants and the high permeability of the sandy tailings deposits, recharge of the alluvial aquifer from overlying tailings adjacent to the creek may occur. This water may be highly contaminated with metals if the vadose zone has reduced pH (<4.5 to 5.0) or low Eh (<50 to -50 mv) conditions.

Discharges from the Weed Concentrator may create a downward component to ground-water movement in the upper MSD area, driving contaminants to depth. A postulated fault in the vicinity of Montana Street may be causing contaminated ground water to surface in the area.

4.3.3 Fate

The Surface Water and Point Source Investigation (Appendix A) identified ground water inflows as a significant source of metals loading to Silver Bow Creek.

Ground-water and sediment contributions to Silver Bow Creek are presented in Table 4-2 for the entire RI period. The ground-water inputs shown were extrapolated from low-flow conditions; high-flow inputs were assumed to be similar. The comparison shows that ground water entering the creek between Montana Street and the Colorado Tailings is a major source of copper, zinc, arsenic, cadmium, and sulfate to Silver Bow Creek. Previously deposited channel or bank sediments appear to be mobilized during higher flows in two areas, though flows were probably not high enough to cause significant bank erosion during this RI.

TABLE 4-2

CONTRIBUTIONS BY NON-POINT SOURCES TO SILVER BOW CREEK
OVER THE ENTIRE RI PERIOD

Parameter	GROUND WATER			BANK OR CHANNEL SEDIMENT ENTRAINMENT[a]	
	Metro Storm Drain	Montana Street to Colorado Tailings	Along Colorado Tailings	SS-07 to SS-10 (SED1)	SS-13 to SS-16 (SED2)
Flow ($10^6 ft^3$)	9.1	30.2	26.9	--	--
Sulfate (lbs.)	376000	401000	246000	--	--
Cu (lbs.)	412	2551	2452	1645	1561
Zn (lbs.)	5870	5428	12188	1764	1855
Fe (lbs.)	2570	0	5036	10829	9240
As (lbs.)	7.1	63.4	139.2	154	154
Pb (lbs.)	3.1	11.7	16.6	224	315
Cd (lbs.)	15.4	17.0	27.9	--	--

Note:

(a) Primarily channel sediment re-entrainment, deposited from another source.

It is difficult to delineate specific areas (e.g., Butte Reduction Works or Colorado Tailings) as being responsible for a quantifiable percentage of the metals load in Silver Bow Creek. A portion of ground-water contamination in one area moves through the subsurface and discharges to Silver Bow Creek in another, downgradient area. Because of this movement, absolute quantification of the ground-water impact in a specific area on metals loading in Silver Bow Creek is not possible.

4.3.4 Severity and Extent of Contamination

This RI found definite evidence of ground-water contamination in the Silver Bow Creek study area. This contamination indicates a severely degraded resource and may pose hazards to human health, as well as to aquatic life and the environment. Limitations on the present and future use of ground-water resources is an additional problem.

Federal drinking water standards were exceeded for most parameters at several wells sampled in the RI study area (Table 2-5). Concentration exceedences were measured for arsenic, cadmium, copper, iron, lead, zinc, and sulfate. The majority of the drinking water exceedences for individual metals and sulfate occurred in monitoring wells in the MSD area and upper Silver Bow Creek. Domestic wells that exhibited exceedences of Federal drinking water standards are identified in Table 4-3. Most of these exceedences were for secondary standards; an exception was cadmium, which exceeded

TABLE 4-3

SUMMARY OF DOMESTIC WELLS[a] EXHIBITING FEDERAL DRINKING WATER STANDARD EXCEEDENCES

Sulfate	Cadmium	Iron	Arsenic	Zinc
DW-131	DW-206	DW-131	DW-230[b]	DW-132
DW-132		DW-336		
DW-202		DW-337		
DW-207				
DW-311				
DW-314				
DW-318				
DW-504				

Notes:

(a) Well locations shown on Map 4-1.

(b) Exceedence measured was for total fraction; corresponding dissolved fraction was less than standard of 0.05 mg/L.

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primary standards at one domestic well. Few exceedences of metal parameters were measured in any domestic wells sampled, although several wells approached the standard for arsenic (0.05 mg/L).

The extent of ground-water contamination in the RI study area was identified in general; exact boundaries of degraded ground water were not discerned. Ground-water contamination is most prominent in the MSD area and upper Silver Bow Creek; it is associated with the Silver Bow Creek alluvium and underlying unconsolidated material aquifers. The shallow portions of the aquifers are typically most degraded 5-6 ft. (depending on location); ground-water quality generally improves with depth. Bedrock ground water was not investigated.

Ground water underlying streamside tailings deposits in areas downstream from Rocker generally is not contaminated. Some samples indicate the upper portion of the alluvial aquifer underlying the Ramsay Flats tailings deposit is degraded slightly when compared with deeper portions of the aquifer. Tailings deposits on the Clark Fork River floodplain may degrade shallow ground water locally, but impacts were not documented during the RI. Floodplain tailings deposits occur at least as far downstream as Gold Creek. Because precipitation was below normal, the impact that overlying tailings exert on shallow ground-water quality may not have been completely characterized during the RI.

4.4 RECOMMENDATIONS

This section recommends additional data collection that may be necessary for the completion of the feasibility study on Silver Bow Creek. Justification for each of the data needs also is provided. Additional data are needed in three areas:

- Further delineation of the source and extent of ground-water contamination in the upper MSD area and in the vicinity of the Butte Reduction Works tailings impoundments. Although RI data identified these areas as sources of ground-water contamination, data were insufficient to delineate the extent of affected ground water or to ascertain geochemical mechanisms causing release of contaminants. Further characterization is required for buried tailings in areas contributing most to the degradation of water quality in the MSD and upper Silver Bow Creek (Parrot and Butte Reduction Works tailings).

- An analysis of historic water quality data (if available) from process ponds located on the Weed Concentrator complex and associated discharges to the MSD. This analysis would help ascertain the potential of this site as a past or future source of ground-water contamination. Current ground-water quality conditions in the area may be a result of this historic contaminant source, which was not evaluated during the RI because it was not part of the defined study area.

- Continued characterization of the vadose zone to further calibrate geochemical and water budget models developed for the RI study area. These data are important because although major ground-water contamination at Ramsay Flats was not suggested by the study, soil chemistry and suction lysimeter results indicate that metal flux to ground water is likely if significant direct recharge occurs through the tailings. Therefore, studies performed during a year of average or above-average precipitation would more accurately characterize impacts of surface tailings.

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5.0 WARM SPRINGS PONDS INVESTIGATION

The Warm Springs Ponds are one of the defined study areas from the Surface Water and Point Source Investigation and the Ground Water and Tailings Investigation. The unique nature of the Warm Springs Ponds within the Silver Bow Creek/Upper Clark Form River system made a separate final report on the area more useful than in combination with the other study areas (See Appendix C). However, the Warm Springs Ponds are part of the continuous flow of surface water from Butte to Deer Lodge, and are as influenced by upstream sites as they influence downstream sites.

The Warm Springs Ponds are the earliest attempts to limit downstream effects of mining. They are standing bodies of water in an otherwise flowing stream. Water moves from the treatment ponds into the upper Clark Fork River after being impounded for a period of time. In addition, ground-water exchange with the pond system also is evident.

The study area of the Warm Springs Ponds extends from the upper pH shack on Silver Bow Creek to the discharge at Pond 2, and includes the Mill-Willow Bypass, the Opportunity Ponds, and the Wildlife Ponds.

5.1 OBJECTIVES

The objectives of the Warm Springs Treatment Ponds Investigation were to determine the following:

- The spatial and temporal variations in surface-water quality and quantity;
- The effectiveness of the ponds in removing metals from the inflow water and the processes involved;
- The interrelationships of surface and ground waters in the area and how they affect downstream resources; and
- The expected operating life of the pond system.

The spatial and temporal variation of the surface-water quality and quantity essentially describes the severity and extent of surface-water contamination. It also aids the identification of contaminant sources, improves the understanding of toxic effects, and allows selection of appropriate remedial actions. The results of this study help determine the relative importance of the surface- and ground-water pathways, and thereby aid in the selection of remedial alternatives.

5.2 INVESTIGATION METHODS

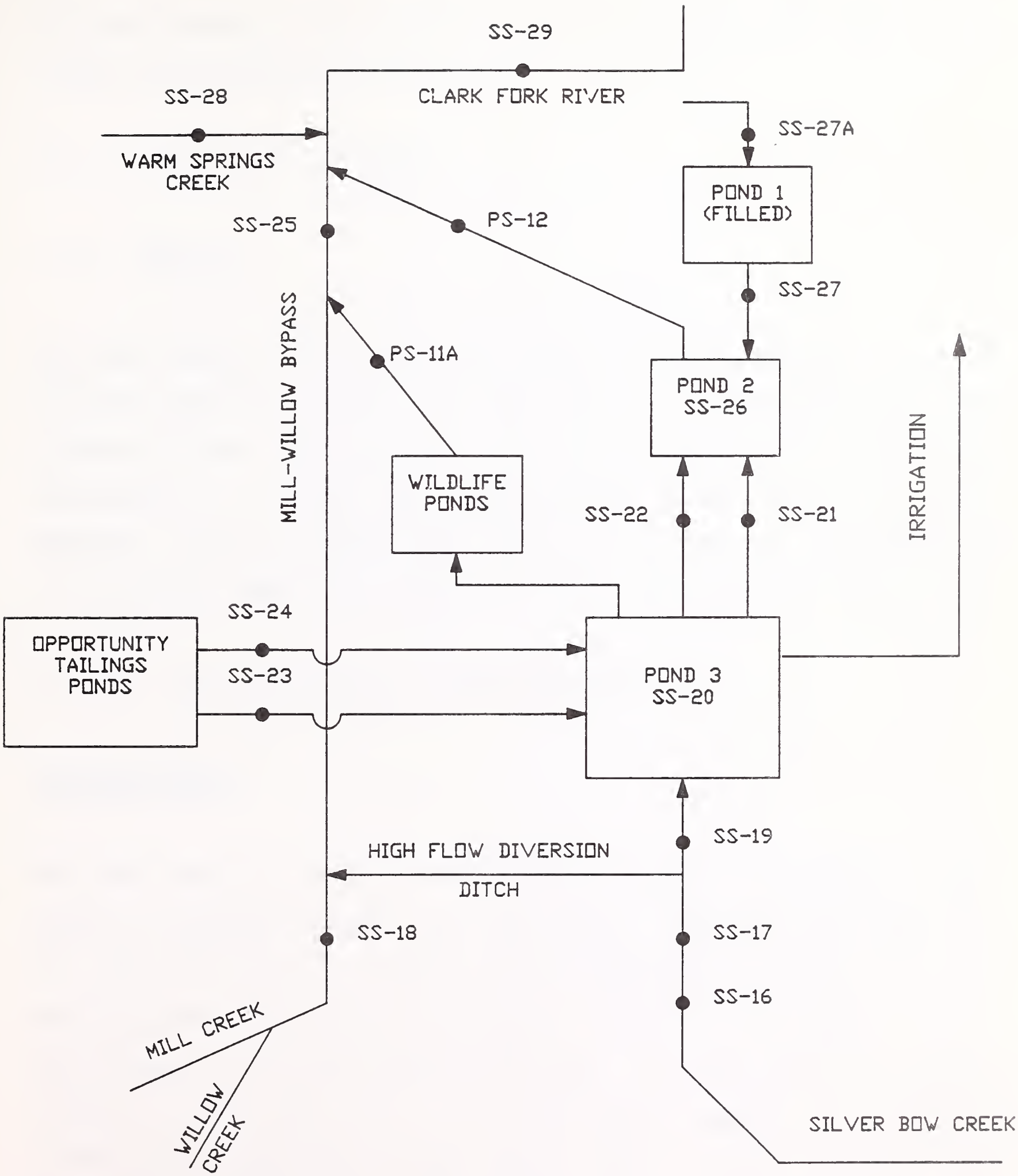
The Warm Springs Ponds Investigation primarily studied the following elements: copper, zinc, iron, lead, arsenic, and cadmium. Other parameters measured were used to aid in identifying contaminant sources, defining the chemistry of the metals, understanding

the role of algae in metals transport, and evaluating toxicity of the metals.

With the exception of studies performed since February 1983, historical water quality data for the Warm Springs Ponds do not reflect current conditions. The RI supplies data that describe the lasting impacts of mining on the Warm Springs Ponds area, impacts that were partially reduced by suspension of mining in Butte. Several other data gaps in previous studies are filled by the RI:

- Very few of the earlier studies collected samples from enough stations to allow identification of contaminant sources. Since suspension of mining at Butte Operations, only the Montana Department of Health and Environmental Sciences' (MDHES) Water Quality Bureau (WQB) study of April 1983 provides any such data.
- Most of the studies, with the exception of the United States Environmental Protection Agency (USEPA) studies, did not analyze for dissolved metals. This lack makes identification of sources more difficult and understanding of the metals transport mechanisms nearly impossible.
- Metals analyzed in previous studies were usually limited to copper and zinc.
- None of the previous studies collected enough data to complete a mass balance analysis of the pond system.

SBC RI data on the Warm Springs Ponds were collected from November 1984 to September 1985. Field data collected included pH, temperature, conductivity, and flow (where appropriate). Water and bottom sediment samples were analyzed for major cations, major anions, and selected trace elements. Station locations are shown on Map 5-1. Meteorological data were collected and surveys of the pond bottoms



MAP 5-1

SCHEMATIC DIAGRAM OF WARM SPRINGS PONDS
AREA SAMPLING STATIONS (NOT TO SCALE)

were performed to aid in volumetric calculations. Data and discussions are presented in Appendix C.

5.3 INVESTIGATION FINDINGS

5.3.1 Sources

The Warm Springs Ponds were constructed to control metals contamination delivered by Silver Bow Creek and the Opportunity Ponds that otherwise would flow into the Clark Fork River. They should act, therefore, as a sink for contamination rather than a source. However, several measured and potential sources of contamination to the Clark Fork River exist in the Warm Springs Ponds area.

5.3.1.1 Measured Sources of Contamination

Surface Water

The Warm Springs Ponds generally act as a sink for sediment, total metals, dissolved metals, and nutrients. However, the ponds are not 100% efficient in trapping metals delivered by Silver Bow Creek and the Opportunity Ponds discharges and can be considered a source of contamination to the Clark Fork River. Another source of contamination to the Clark Fork is the Mill-Willow Bypass which receives contaminants, apparently from ground water, along its course and delivers them to the Clark Fork River. These sources are summar-

ized and compared in Table 5-1 regarding contaminant loads delivered to the Clark Fork.

TABLE 5-1
SOURCES OF CONTAMINATION TO THE CLARK FORK RIVER[a]

	Pond 2 Discharge (PS-12)		Wildlife Ponds Discharge (PS-11A)		Mill-Willow Bypass (SS-25)[b]	
	Load (lbs)	%[c]	Load (lbs)	%[c]	Load (lbs)	%[c]
Flow	--	40	--	4	--	1
Sulfate	10,175,025	46[d]	1,173,975	5	2,911,413	13[d]
Cu(T)	4,834	50[d]	194	2	774	8[d]
Zn(T)	14,138	74[d]	300	2	1,242	6[d]
Fe(T)	45,135	45[d]	829	1	10,146	10[d]
As(T)	879	38	110	5	17	1
Pb(T)	424	64[d]	6	1	0	0
Cd(T)	10	43	0	0	3	13[d]

(a) Includes measured loads delivered during the entire RI period, December 1984 - August 1985.

(b) Corrected for upstream loads (SS-18 and PS-11A).

(c) Percentage of inputs to the Clark Fork River at the confluence with Warm Springs Creek.

(d) Percent load significantly higher than percent flow, indicating water quality is degraded.

The table shows that the Pond 2 discharge was the largest contributor of contaminant loads to the Clark Fork River during this RI and significantly degraded water quality with sulfate, copper, zinc, iron, and lead. The Mill-Willow Bypass degraded water quality with sulfate, copper, zinc, iron, and cadmium. Surface water in the Clark Fork River is degraded by these two sources, although they are not the ultimate sources of contamination. Silver Bow Creek and the Opportunity Pond discharges are sources to the Pond 2

discharge, and ground water is the source of contaminants to the Mill-Willow Bypass.

Ground Water

Ground-water quality data indicate that the Warm Springs Ponds are sources of ground-water contamination. Shallow ground water below the Pond 1 berm (WSP-2B) contains elevated levels of most constituents measured, when compared to ground water sampled upgradient of the ponds. The ground-water quality observed in shallow (<25 feet deep) ground-water monitoring wells downgradient of Pond 1 is comparable to surface water observed in the Pond 1 pumpback (SS-27A) which recycles seepage water that collects below the Pond 1 berm back to the pond system. The similarity of the water quality of these two sources indicates that seepage water is not completely contained by the pumpback, and that it moves north from the ponds as ground water.

The calculated direction of travel of contaminated ground water downgradient of the Pond 1 berm is to the north, at a gradient of about 0.4%. No hydraulic data are available for this area with which to calculate the rate of movement of the contaminants. Monitoring well WSP-5, located about 0.5 miles north of Pond 1 and near the Clark Fork River, also contains levels of dissolved metals well above background levels. This measurement suggests that contaminated ground water is present at least this far north. Surface-water data presented in Appendix A, Surface-Water and Point-

Source Investigation, show no measurable effects of contaminated ground-water inflow to the Clark Fork River.

Contaminated ground water below Pond 1 appears to occur mainly in the eastern portion of the valley bottom. Two factors may contribute to this occurrence. First, the eastern portion of the valley contains the alluvial gravels of the historic Silver Bow Creek channel, which may allow preferential ground-water movement in the area. Second, water is ponded in the northeast corner of Pond 1, and its presence is maintained by the Pond 1 pumpback. The presence of this body of water may locally increase the hydraulic gradient and therefore the rate of ground-water movement, in the eastern portion of the valley below the Pond 1 berm.

Other evidence of ground-water contamination from the Warm Springs Ponds is found in the Mill-Willow Bypass. A specific conductance (SC) survey of the Mill-Willow Bypass found highly conductive water near both banks of the stream. Chemical analyses of surface-water samples collected in the Mill-Willow Bypass show increases in sulfate, total iron and cadmium, and dissolved copper and zinc in this reach. Although bank erosion and channel sediments could be contributing some of the observed gains, concentration and flow increases are observed even at the lowest flows, suggesting ground-water inflow has a significant impact on water quality in the Mill-Willow Bypass.

The specific conductance survey suggested that ground-water contamination is entering the Mill-Willow Bypass primarily from the Opportunity Ponds, and in less significant amounts from the Warm Springs Ponds. This observation is confirmed by ground-water quality data, which indicates the presence of degraded ground-water quality in the area east and northeast of the Opportunity Ponds. This ground-water system moves to the northeast and at least partially intersects the Mill-Willow Bypass.

5.3.1.2 Potential Sources of Contamination

High Flow Bypasses

The Warm Springs Ponds are not designed to contain major flood events. A bypass channel constructed upstream of the Warm Springs Ponds was designed to divert Silver Bow Creek flows greater than about 700 cfs around the ponds and directly into the Mill-Willow Bypass (U.S. Army Corps of Engineers 1978). From the Mill-Willow Bypass, the water continues untreated into the Clark Fork River.

The inlet structure to the Warm Springs Ponds is gated just below the diversion ditch. Debris can collect on the gates and cause water to back up, possibly causing failure of the dike and bypass of the ponds at flows much less than 700 cfs; for example, the dike at the head of the diversion ditch washed out when flow into the ponds was only 185 cfs, on June 2, 1985. Silver Bow Creek water probably bypasses the Warm Springs Ponds an average of once per

year. No water quality samples were taken on Silver Bow Creek during a period when the ponds were bypassed; however, historic data have shown dramatic increases in TSS and most metals in the Clark Fork River following a bypass event. During high-flow conditions that cause the diversion ditch to become functional, the Warm Springs Pond system is ineffective in protecting the Clark Fork River from contaminated Silver Bow Creek water.

Pond Failure

The 100-year flood was estimated by Hydrometrics (1983a) to be 3600 cfs, and the pond structures would probably withstand a flood of that magnitude. However, during floods slightly larger than the 100-year flood, risk of pond failure increases significantly. At flows greater than 4000 cfs on Silver Bow Creek, the diversion structure at the upper pH shack would no longer function reliably and the full flood would possibly enter the Mill-Willow Bypass through the diversion ditch (IECO 1981). This flood probably would cause failure of at least one of the pond berms and loss of the contents of that pond (U.S. Army Corps of Engineers 1978). Pond 3 could fail directly when its outflow reached 5600 cfs, and a flow of 7000 cfs would overtop both Ponds 2 and 3, causing their failure (IECO 1981).

Failure of the ponds also could occur if an earthquake weakened the pond embankments. IECO (1981) estimated that the Continental Fault east of Butte could produce an earthquake of Richter magnitude

6.9, which would be sufficient to cause failure of the embankments. The study also found that 3- to 4-foot berms placed at the toes of the unstable sections of the pond embankments would improve the safety factor to an acceptable level.

Failure of the Warm Springs Ponds embankments would release large amounts of mining and milling wastes to the Clark Fork River. Under those conditions, the Warm Springs Ponds would become a major source of contamination.

Pond Life Expectancy

As the ponds fill, their capability to trap sediment and precipitate metals will be reduced, and Silver Bow Creek will receive less and less treatment as it flows into the Clark Fork River. As the ponds reach their capacity, they may begin to act as a source of contamination. Previously deposited material could be eroded gradually by the shifting channel within the filled ponds. Sediment yield calculation for the Silver Bow Creek drainage estimates the remaining life for Pond 3 at approximately 120 years. This calculations assumes no major changes in the ponds' operation or design for the next 100 years.

Recharge Through Streambank Tailings

Large quantities of tailings with elevated metal levels have been deposited along the Silver Bow Creek-Clark Fork River floodplain.

Depth of the tailings varies from near zero to six feet or more. In the wells sampled, the solubility of metals in these deposits appears fairly low due to the high pH levels. Based on that limited sampling, ground-water recharge or surface-water percolation through the surficial tailings appears not to constitute potential contaminant source to ground water. However, if low pH or low Eh conditions exist in a portion of these deposits, metal solubilities may be greatly increased and may allow contaminant migration into ground water.

5.3.2 Fate

Pond system performance calculated for the RI study period showed a variety of trends which were consistent with earlier studies.

During the summer the ponds were very efficient at removing most contaminants from the influent water, because of lower flow rates which allow settling and deliver lower contaminant loads, and higher pH in the ponds which cause precipitation of dissolved metals and is probably related to increased algal activity. The high pH also appeared to liberate some arsenic, possibly by desorption.

Winter data show the ponds were much less efficient. Lower pH levels allowed some dissolved copper, zinc, and cadmium to travel through the pond system without being precipitated and removed.

Higher flows during the spring significantly lowered pond efficiencies for most metals by both delivering higher contaminant loads and reducing residence times. Solid phases of copper, zinc, and iron as well as lead and arsenic were released in large quantities during this period. Sulfate reacted inversely to flow, being highest during low flows in summer and winter. Hydrologic regime is the most important mechanism governing the amount of contaminants released to the Clark Fork River by the ponds.

Algae may be important in the Warm Springs Ponds system by influencing the pH of the ponds and through bioaccumulation of metals. This was examined in the Algae Report, Appendix D, Part 1.

Pond system performance may be significantly improved by minor modifications to current operating procedures. First, a structure or method to prevent the inlet structure at SS-19 from becoming blocked by debris would prevent pond bypasses at flows lower than design (~700 cfs). This action would not prevent bypasses of extreme flows but would remedy unnecessary releases of untreated water to the Clark Fork River. Secondly, more effective pH control could increase the amount of contaminants trapped by the pond system. Wide pH fluctuations allow contaminants to travel through the ponds: low pH in winter (6.8 - 8.0) does not effectively precipitate dissolved zinc and copper, high pH in summer (9.0 - 10) allows arsenic to desorb and be released. Maintaining pH in the range of 8.0 - 9.0 all year may effectively reduce these kinds of releases.

Table 5-2 presents total loads released to the Clark Fork River by each of these mechanisms and compares them to a bypass event measured by the Water Quality Bureau (WQB) in early 1986.

TABLE 5-2
COMPARISON OF CONTAMINANT RELEASE MECHANISMS AFFECTING THE WARM SPRINGS PONDS

Event	Duration	Cu (lbs)	Zn (lbs)	As (lbs)
Winter Low pH	42 days	777	3776	105
Summer High pH	84 days	319	420	277
Spring High flow	45 days	1917	3731	333
Pond Bypass[a]	2 days	1100	1684	109

Note:
(a) Data collected by the Montana Water Quality Bureau; Feb. 25, 1986, shortly after a bypass event.

5.3.3 Severity and Extent of Contamination

The pumpback to Pond 1, the Mill-Willow Bypass, and the Opportunity Pond discharges are all open water bodies accessible to the public, and may represent a risk to human health from surface-water contamination. Federal primary drinking water standards for metals were not exceeded in the two discharges from the Warm Springs Treatment Ponds (PS-11A and PS-12) during the RI and generally were not exceeded in the ponds themselves (SS-20 and SS-26; Table 2-4). The standard for lead (0.05 mg/L) was exceeded by both Opportunity Pond discharges (SS-23 and SS-24) on one date. The drinking water standard for arsenic (0.05 mg/L) was exceeded at both stations on the Mill-Willow Bypass during a relatively high-flow event, but this

arsenic exceedence probably did not originate from contamination in Silver Bow Creek. The Pond 1 Pumpback (SS-27A) was the only station to regularly exceed the primary drinking water standard for arsenic.

The acute aquatic life criterion (one-hour average concentration) for copper is usually exceeded in the ponds, and the acute criterion for zinc is occasionally exceeded in the ponds but not in the ponds' discharges (Table 2-3). These conclusions are based on total metals analyses and may therefore exaggerate the aquatic life toxicity problems in the Warm Springs Ponds. Fish were observed in Pond 3 and the Wildlife Ponds during the study period; hence, the use of total metals concentrations to determine aquatic life toxicity may overestimate toxicity for adult trout. However, the presence of fish does not necessarily mean that fish can successfully perform all life functions (e.g., reproduction).

The Mill-Willow Bypass also exhibits chronic aquatic life toxicity for copper and zinc and acute toxicity for copper. The incidence of chronic toxicity of zinc increases greatly along the course of the Mill-Willow Bypass.

Ground water in the Warm Springs Ponds area is contaminated downgradient of the Warm Springs Ponds and the Opportunity Ponds. Federal drinking water standards are exceeded for sulfate, arsenic, iron, and fluoride in these areas. No domestic wells are in the vicinity of the contaminated ground water, so no apparent or immediate threat exists to public health.

The Warm Springs Ponds sediments contain some of the highest concentrations of toxic metals to be found in the RI study area and pose a potential threat to water quality in the Clark Fork River for an indefinite period.

5.4 RECOMMENDATIONS

The Warm Springs Ponds require further study because the present data base does not allow a complete evaluation of the effect of a pond bypass event, the severity and extent of ground-water contamination, and the effects of pond algae on pond pH and metals transport out of the ponds. Additional pond sediment data may be necessary, and computer modelling of pond chemistry may be required. Additional data are needed in five areas:

- Pond bypass event. The relationship of sediment transport to flow is roughly exponential. A very large amount of contaminants may bypass the pond system entirely during one of these events. No data were collected during this RI that can be used to measure the amount of contaminants released and the relative importance of such events. Other data collected by the WQB indicate that bypasses are a major source of contaminants to the Clark Fork River (Table 5-2). At least one of these diversions should be gaged, sampled, and analyzed for total, acid soluble, and dissolved forms of aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc. Time integration of samples would be appropriate for this sampling.

- Ground-Water Contamination. A contaminant plume has been demonstrated by this RI downgradient from the pond system at least 0.5 miles. The downgradient and lateral extent of this plume has not been determined. To determine the extent of the contaminant plume, additional monitoring wells must be placed downgradient from existing wells and sampled. The RI also showed that poor quality ground water enters

the Mill-Willow Bypass from both sides. To quantify the inflow due to the Warm Springs Ponds, a number of piezometers should be installed along the western berms of Ponds 2 and 3. Used in conjunction with permeability data and water levels in the ponds and the Mill-Willow Bypass, these data would allow determination of flow rates through the berms. The determination of contaminant loads to the Mill-Willow Bypass due to pond seepage would require either placement of ground-water monitoring wells at several points along the western berms of the ponds or sampling of piezometer wells.

- Pond algae studies. If the Feasibility Study finds that more data are needed on the role of algae in the ponds, then an algae-sampling program should be implemented. A sampling program which includes algae counts, total suspended solids (TSS), volatile suspended solids (VSS), and total organic carbon (TOC), as well as metals analyses, should be able to demonstrate if algae play a role in metal transport. The sampling program for algae must include sufficient baseline data to show that changes in algae counts are indeed correlated in time with water quality parameters. Measurements should be taken at the inflow to the ponds, in the ponds themselves, and at the two pond outflows. Water samples from the Warm Springs Ponds were collected during daylight, when pH increases from carbon dioxide assimilation would be greatest. Significant pH decreases during the night may occur from algal respiration, which would be accompanied by increased dissolved metals concentrations. The diurnal pH pattern within the pond system could be adequately determined by taking on-site hourly pH measurements for a 24-hour period. The daytime weather should be sunny to show the maximum diurnal variation. Correlations of continuous and close-term periodic pH variations within the pond system and at discharge points would provide an excellent basis to analyze the potential role of algae within the pond system. Concurrent water quality sampling for selected metals in dissolved, acid soluble, and total forms would yield valuable information regarding algal pH control.

- Pond sediment characterization. Fourteen pond bottom sediment samples were taken from the Warm Springs Ponds during the RI. The analytical results indicate very high total metals concentrations. Accurate determination of the degree and extent of sediment contamination is necessary information when developing clean-up alternatives; systematic sampling of the pond sediments is necessary to determine both the volume of sediments and the variation of metals concentrations with depth. Core samples should be obtained that show the vertical extent of the sediments. This characterization is recommended only if the removal of these sediments is being seriously considered as a remedial option.

- Geochemical computer modelling. More rigorous analysis of mechanisms and/or the metal-phase distributions within the ponds may be useful for the feasibility study. Several computer modelling codes are available for determining geochemical equilibria and should be employed if necessary. Additional data would be required for input to most of these programs (e.g., Eh measurements).

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6.0 FLORA INVESTIGATIONS

Three SBC investigations studied the plant life associated with Silver Bow Creek:

- Algae;
- Riparian Vegetation; and
- Agriculture.

These studies showed that the vegetation in and near the creek, or irrigated with creek water, was affected by the contaminants found in the hydrologic system. Algae and some irrigated crops exhibited bioaccumulation of metals. Plant distribution along the stream bank was determined by contaminant levels, soil factors, and water regime.

6.1 ALGAE INVESTIGATION

6.1.1 Objectives

After reviewing historical data, a field study was proposed in the SBC RI Work Plan (MultiTech and Stiller and Associates 1984a) to evaluate the role of algae in metal transport. This field study was designed (1) to measure the metal content of attached algae, (2) to determine the species composition of attached algae, and (3) to determine if algae were concentrating metals, using the water quality data generated by other RI studies. Sampling stations were

located on Silver Bow Creek, the Warm Springs Ponds, and on the Clark Fork River at Deer Lodge.

Due to vandalism and bedload scouring of periphytometer samplers, the proposed approach did not provide any usable data. The Interim Algae Investigation Report documents the results of the field studies (MultiTech 1985).

Following completion of the first sampling episode, a newly acquired report suggested that the proposed methodology would not provide the required data, even without vandalism or bedload scouring. Newman et al. (1985) used a similar methodology (algae collection on glass slides) to investigate algae concentration of metals in coal-ash settling basins. They found no correlations between the concentrations of arsenic, cadmium, chromium, copper, and zinc and microfloral cell densities or percent ash free weight. Furthermore, Newman et al. (1985) found by using scanning electron microscopy and X-ray analysis that non-biological sediment trapped on the samplers prevented an accurate measurement of the metal content of the attached algae.

6.1.2 Investigation Methods

To avoid the problems associated with an in situ approach measuring algae metal content, the Interim Algae Investigation Report suggested a laboratory study which would culture collected Silver Bow Creek algae in spiked lab water to investigate algae concentration of

metals. Budgetary constraints prevented the approval of this approach by the Montana Department of Health and Environmental Sciences (MDHES). Instead, the approved approach utilized the limited 1985 algae data from the SBC RI and literature data on algae concentration of metals to evaluate the potential for algae transport of metals. This approach was narrowed in scope, to an evaluation of algae in metals transport out of the Warm Springs Ponds during late winter and early spring because (1) the algae data for 1985 were collected during this period and (2) algae have been suspected of playing a major role in metal spikes in the Clark Fork River during this time of year. Other mechanisms that may account for elevated metals concentrations in the pond discharge are discussed in the Warm Springs Ponds Investigaton Report, Appendix C.

6.1.3 Investigation Findings

The literature shows certain algae species are capable of concentrating metals from the water column, and some of these species were found in the Warm Springs Ponds. Previously published data (Shambaugh 1983) indicated that algae in the Warm Springs Ponds have higher concentration of metals than water samples collected from the ponds.

The SBC RI data from spring 1985 and the literature discussions indicated algae in Warm Springs Pond 2 took metals out of the water entering the ponds; furthermore, some of the algae were retained

within and some of the algae were released from the ponds. Other potential mechanisms, such as sedimentation of metal-bearing particulates, also may account for lower concentrations of total metals in the Pond 2 discharge.

6.1.4 Recommendations

Before algae can be given serious consideration as a control technology for Silver Bow Creek/Clark Fork River, a more definitive evaluation of their role in metals transport must be made. Two approaches are suggested:

- Through a program of late winter/spring water and algae sampling, develop a metals "budget" for one of the ponds and determine if and how it correlates to changes in the algal population within the pond. This metals budget would reveal if the pond studied is a metals "sink" and whether the removal of metal from the water is associated with blooms of algae;
- Undertake the culturing program described in the SBC RI Algae Investigation Interim Report (MultiTech 1985).

6.2 RIPARIAN VEGETATION INVESTIGATION

6.2.1 Objectives

Documenting the location and extent of tailings deposits was identified as a work element during RI planning. These data can be used during the feasibility study to identify operable units and potential corrective action sites, and to characterize contaminant sources. Only the geographic extent of the tailings deposits was

to be documented in the vegetation mapping effort, as more costly volume determinations were postponed until the feasibility study so that those determinations could be focused on the areas shown to be major contaminant contributors by the RI surface-water and groundwater studies.

To supplement the geologic, hydrologic, and biologic data developed by the other RI studies and to help characterize the Silver Bow Creek site, mapping of the riparian vegetation of the site also was identified as a RI work element during RI planning. This information will be useful in the feasibility study to identify potential treatment facility locations and potential borrow areas.

To meet the needs of the feasibility study and to use RI resources most effectively, mapping units selected for mapping vegetation were to be broad-based, easily recognizable types that differentiated the riparian vegetation of the site. Detailed, undisturbed community composition descriptions of the identified units were not necessary. Previous studies by Hydrometrics (1983a,b,c) and Neher and Weisel (1977) adequately documented those riparian species that are tolerant of contaminated conditions, so detailed species composition descriptions of these areas were not judged as necessary for the RI.

The objective of the Riparian Vegetation Investigation was to map the tailings and riparian vegetation at the largest available scale,

using easily recognizable mapping units that differentiated the riparian vegetation of the site.

6.2.2 Investigation Methods

The objective of this investigation was accomplished in five activities:

- Acquisition, review, and selection of appropriate existing aerial photography;
- Selection of mapping unit classification system;
- Mapping of units;
- Field verification of mapping units; and
- Final map preparation and data reporting.

Data and maps resulting from this investigation are documented in Appendix D, Part 2.

6.2.3 Investigation Findings

Tailings apparent from aerial photography covered approximately 1,133 acres of the study area from Butte to Deer Lodge. The geographic location and coverage of 13 other mapping units based on the existing vegetation are shown in the maps attached to Appendix D, Part 2. Previous work by Hydrometrics (1983a, b, c) and Neher and Weisel (1977) on locally occurring metals-tolerant plant species indicate dry SBC tailings are colonized by inland salt grass

(Distichlis stricta) and the scorpion plant (Phacelia hastata), and that wet tailings, such as those found at the Warm Springs Ponds, can support a much more diverse community.

6.2.4 Recommendations

No recommendations were made.

6.3 AGRICULTURE INVESTIGATION

6.3.1 Objectives

An RI-related literature review revealed an estimated 5,380 acres of potentially contaminated cropland within Silver Bow, Deer Lodge, and Powell Counties (MultiTech and Stiller and Associates 1984a). The suspected source of cropland contamination was the use of metal-laden water from Silver Bow Creek and the upper Clark Fork River for irrigation. The severity of contamination and consequent economic significance were not estimated.

Four concerns developed during the literature review:

- Whether the areal extent and severity of contamination had abated over time;
- Whether residual contaminants were present at sufficient levels to adversely affect the terrestrial food chain, and consequently become a threat to human health and welfare;

- Whether the irrigated lands also were affected adversely by deposition of heavy metal-laden particulate matter from smelter stack emissions; and

- The need for baseline physicochemical data to evaluate alternative soil treatment and crop/livestock management practices (MultiTech and Stiller and Associates 1984b).

These four concerns determined the objectives of the Agriculture Investigation. The investigation was implemented using a two-phased approach (MultiTech and Stiller and Associates 1984a).

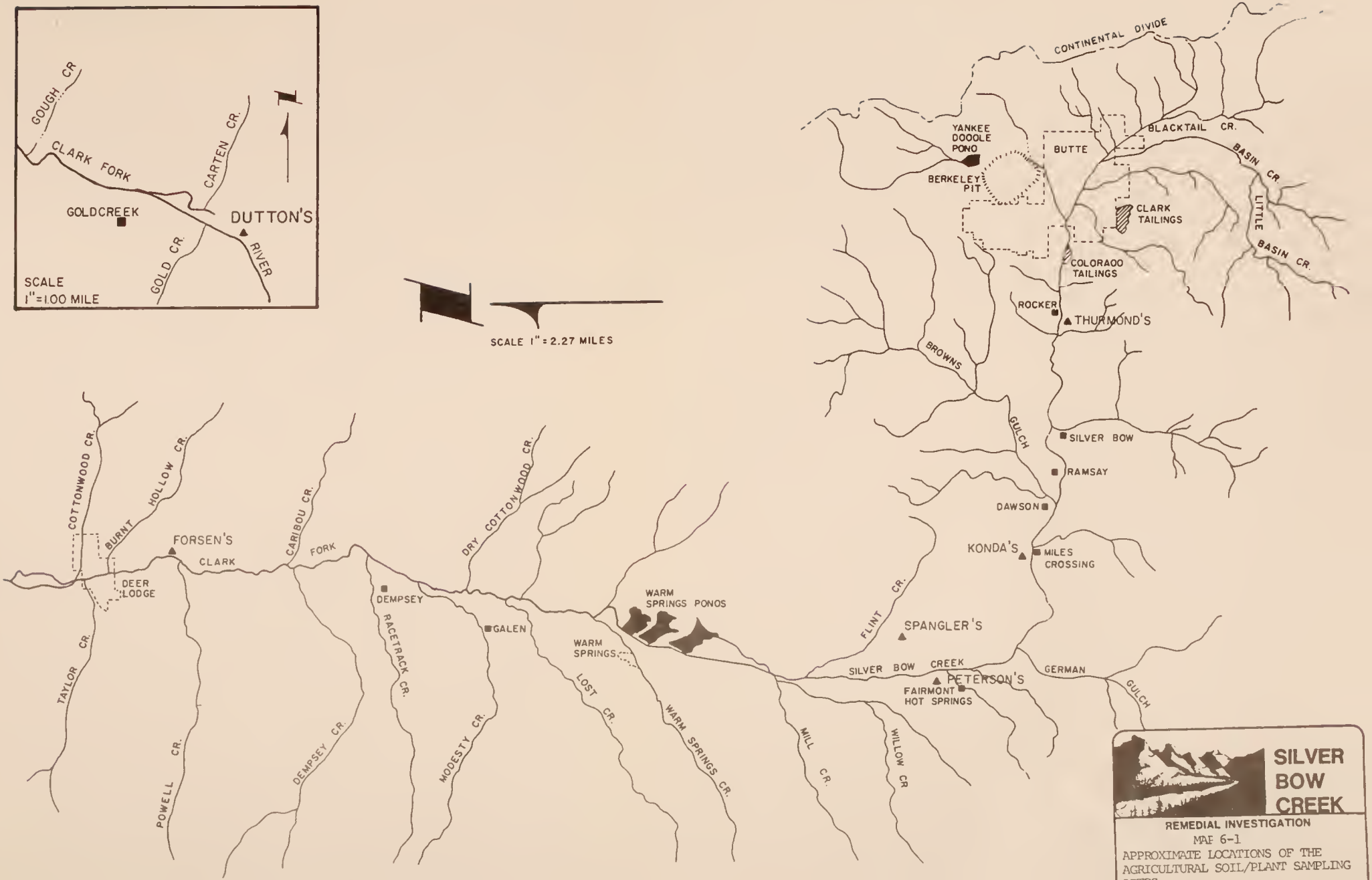
- Phase One--a reconnaissance level effort to refine the preliminary estimate of the extent of heavy metal contamination, plus a preliminary evaluation of the severity of such contamination on irrigated croplands, as a risk to livestock, and to human health and welfare;

- Phase Two--a statistically rigorous evaluation of the effects on agricultural production and/or human health found in Phase One, if approved by MDHES project management. (Phase Two was not initiated during the RI.)

The Phase One effort was divided into the following tasks:

- Task One--utilize existing data and phone interviews to identify land-owners who either knew or strongly suspected adverse agricultural impacts resulting from the use of Silver Bow Creek and/or Clark Fork River waters; and

- Task Two--collect and analyze soil and plant materials from affected and adjacent control sites, calculating levels of statistical confidence or sampling precision after sampling was completed. (See Map 6-1).



SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 6-1

APPROXIMATE LOCATIONS OF THE AGRICULTURAL SOIL/PLANT SAMPLING SITES.

6.3.2 Investigation Methods

Soil and plant samples were collected during the summer of 1985 and analyzed for selected trace elements and reclamation-oriented parameters. The sample data were analyzed statistically and spatially, and compared against environmental assessment criteria (MultiTech and Stiller and Associates 1984a) to address the first three concerns developed during the literature review. The fourth concern was addressed through the analysis of such reclamation-related parameters as plant macronutrient and plant-available heavy metal levels. These analyses were performed for those sites probably affected by exposure to contaminated irrigation water, as well as upgradient control sites. Data and discussion for this investigation are presented in Appendix D, Part 3.

6.3.3 Investigation Findings

Strong circumstantial evidence was found to support the hypothesis that waterborne heavy metal contaminants, originating from upstream mining/mineral processing activities, adversely affected agricultural activities within the study area.

The data indicated a strong heavy metal contamination gradient that decreased in concentration from Thurmond's floodplain site near Butte to Spangler's site A7, which probably received irrigation waters from the Watson Ditch (in turn connected to Silver Bow Creek). Similar observations were made for the Peterson sites,

located adjacent to the Yellow Ditch. A second concentration gradient was observed for the Forsen and Dutton sites: the former received contaminated waters from the E. Valiton Ditch, while the latter has received contaminated materials (mill tailings) from the Butte and Anaconda operations.

In some cases, deposition of heavy metals and increasing acidity from pyrite mineral oxidation were sufficiently severe to prevent vegetative growth. These conditions were particularly evident at the following sites: Konda's A3, Peterson's T13, Spangler's A7, and Forsen's A13. Given the depauperate nature, if not absence, of vegetation at the most severely affected sites, these areas probably represented little danger to livestock; the exceptions to this assessment are heavy metal-tolerant plants growing along the margin of such denuded areas and potential offsite transport by wind and water erosion to adjacent, largely unaffected lands utilized routinely by livestock. However, at several of the less visibly affected sites (e.g. Thurmond's A11, Dutton's A9), cause for concern existed for the ingestion of heavy metals-contaminated soils by livestock during grazing, or from soild particles adhering to the harvested forage/hay.

However, the rural nature and remoteness of most of these affected sites limited the risk to humans via direct contact or ingestion of metals. Respiratory protection from dust generated during any remedial operations (e.g., deep plowing/liming) seems prudent.

Seven concerns developed during the RI:

- Given the available data, whether the areal extent and severity of heavy metals contamination of agricultural lands has abated over time cannot be determined definitively. The persistence of heavy metals in soils is such that lands historically affected probably still are burdened to varying degrees (depending on a host of physicochemical and biological factors which vary from one trace element to another, and from one soil type to another). Furthermore, the field observations were used to "calibrate" additional interpretation of aerial photography for the study area; results of these efforts support the original estimate of approximately 5400 acres of clearly affected lands within the three counties of interest. If more subtle vegetative productivity (yield reduction) effects are included, the above estimate could increase by several-fold, possibly to 18,600 acres within the three-county study area.

- The data indicated that sufficient time has passed since deposition for the more mobile elements (particularly zinc) to begin to concentrate at lower depths in the soil profile; thus, contamination severity has lessened for these elements, but not for those which tend to remain near the surface (e.g., copper, lead).

- As discussed previously, the residual contaminants posed some concern to the terrestrial food chain (as plants growing on contaminated soils can exhibit elevated metals levels), while a minimal threat to human health and welfare appeared evident.

- Contamination by waterborne and airborne trace elements probably occurred at several of the Peterson sites, as judged by comparison to certain soils data collected by Tetra Tech for the Anaconda Smelter RI.

- Airborne heavy metal contamination may have occurred also at the Spangler sites. Studies performed within the Deer Lodge Valley indicate that total levels of arsenic, cadmium, copper, and zinc in surface (0-6 in.) soils and associated plants sampled at distances up to 10-mile radius of the Washoe Smelter's main stack often exceeded their respective biogeochemical background levels. This observation must be tempered by the fact that areal magnitude of contamination varies from one element to another, while particulate deposition patterns for the above elements in surface soils varies non-uniformly with distance and direction from the smelter. Similarly, the marginally elevated levels of total aresenic and cadmium measured at Konda's A1 and Thurmond's A10 (upgradient) sites may have been due to stack emissions from the Colorado and Montana Smelter and/or Butte Reduction Works. Both of these operations were located adjacent to Silver Bow Creek and had

relatively short stacks; the plumes (containing the particularly volatile arsenic and cadmium) would be constrained topographically by the Silver Bow Creek channel and adjacent foothills.

- The best case for waterborne contamination was found at Forsen's site A13.

- The RI study analyses included certain soil and plant measurements useful in evaluating alternative soil treatment and crop management practices during the feasibility studies. However, as the primary objective of this RI was assessing potential heavy metals contamination, the list of reclamation-related parameters tested for was by no means exhaustive. These possible deficiencies are addressed in the following recommendations section.

6.3.4 Recommendations

The investigation results indicated that irrigated agricultural lands were contaminated through use of waters taken from Silver Bow Creek or from the upper Clark Fork River, or by exposure to mill tailings/contaminated floodplain soils. A three-tasked approach is recommended for follow-on work. The application of the analytical screening approach in Figure 6-1 will result in improved demarcation of the contamination's areal extent, refined assessment of the severity of contamination, and evaluation of potential foodchain (metals accumulation) effects.

Task One

In Task One, soils and plant sampling would continue at those irrigated agricultural sites where waterborne heavy metal contamination is either known or suspected. The published results of the

present SBC Agriculture RI (Phase One - Reconnaissance) efforts will probably stimulate the interest and concern of other agricultural landowners within the RI area. Consequently, landowner contacts are expected to be the chief source for sampling sites.

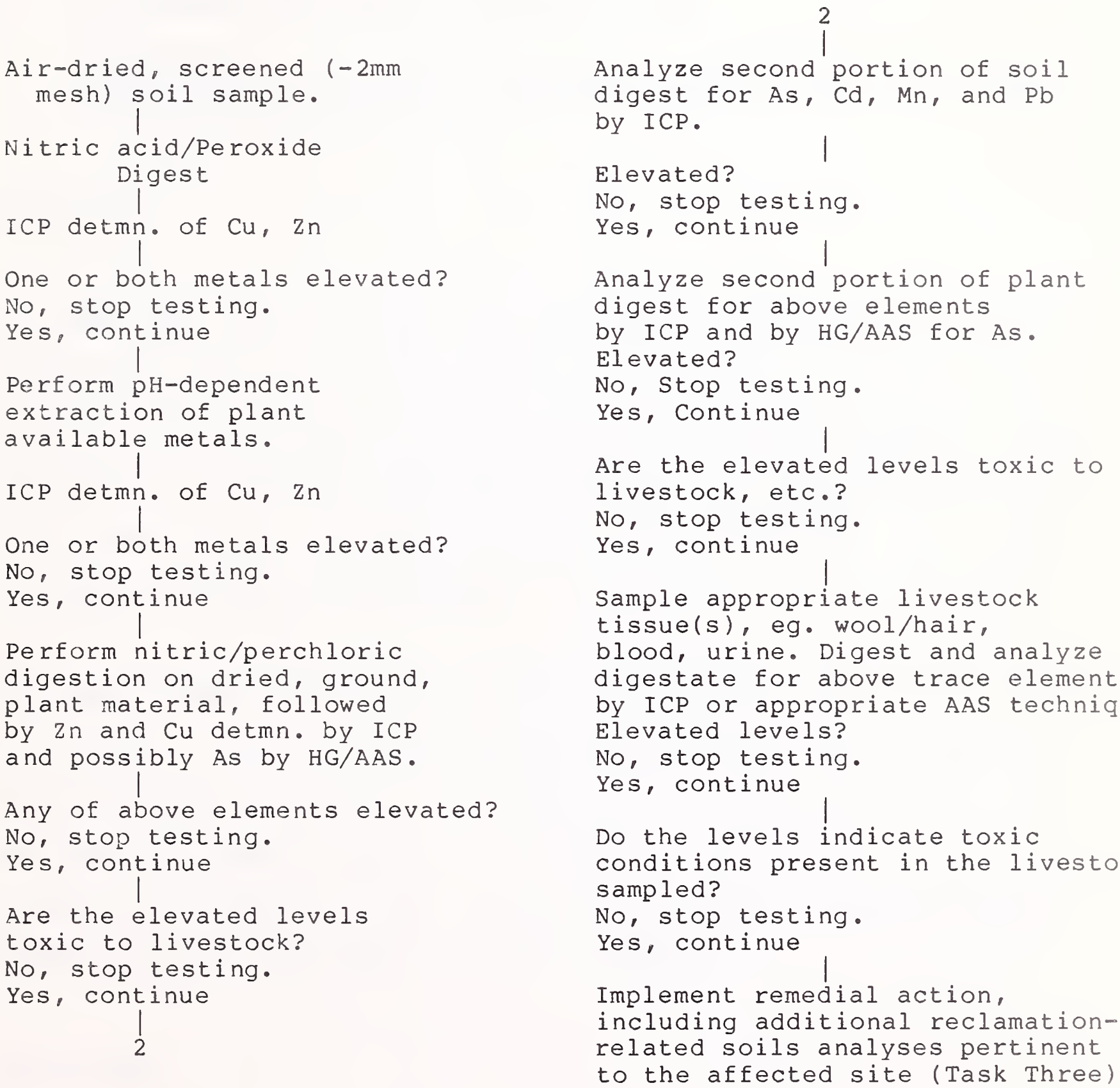
Concurrent with soil/plant sampling, above-ground biomass production (clipping plot) studies would be performed.

Plant and soil sampling, plus clipping plot studies, at fields reputedly contaminated would be accomplished by properly trained seasonal technicians. Composite, representative samples of the upper six (and possibly twelve) inches of each soil profile would be acquired using an Oakfield-type tube sampler. Plant materials would be gathered as performed in the current study's agricultural sampling. The samples would be processed by an approved laboratory. Site-specific production estimates would be acquired.

An impact severity classification system would be created through field observation data; heavy metal levels (in soils and plant materials) statistically correlated with yield figures; "climatologically averaged" biomass production values taken from SCS range site guides; and clipping plot studies performed at geochemical control sites. The approved system then would be used to create an impact assessment map.

The recommended analytical screening process is presented in the left column of Figure 6-1. The task results would be threefold:

FIGURE 6-1
RECOMMENDED ANALYTICAL SCREENING APPROACH FOR CONCLUDING
THE AGRICULTURAL RI


Air-dried, screened (-2mm mesh) soil sample.
Nitric acid/Peroxide Digest
ICP detmn. of Cu, Zn
One or both metals elevated?
No, stop testing.
Yes, continue
Perform pH-dependent extraction of plant available metals.
ICP detmn. of Cu, Zn
One or both metals elevated?
No, stop testing.
Yes, continue
Perform nitric/perchloric digestion on dried, ground, plant material, followed by Zn and Cu detmn. by ICP and possibly As by HG/AAS.
Any of above elements elevated?
No, stop testing.
Yes, continue
Are the elevated levels toxic to livestock?
No, stop testing.
Yes, continue
2
2
Analyze second portion of soil digest for As, Cd, Mn, and Pb by ICP.
Elevated?
No, stop testing.
Yes, continue
Analyze second portion of plant digest for above elements by ICP and by HG/AAS for As.
Elevated?
No, Stop testing.
Yes, Continue
Are the elevated levels toxic to livestock, etc.?
No, stop testing.
Yes, continue
Sample appropriate livestock tissue(s), eg. wool/hair, blood, urine. Digest and analyze digestate for above trace elements by ICP or appropriate AAS techniqu
Elevated levels?
No, stop testing.
Yes, continue
Do the levels indicate toxic conditions present in the livestoc sampled?
No, stop testing.
Yes, continue
Implement remedial action, including additional reclamation-related soils analyses pertinent to the affected site (Task Three).

- Verification of the spatial extent of contaminated lands (possibly as far downstream as the Milltown Reservoir);
- Establishment of an impact severity classification scheme (i.e. one ranging from 100 percent yield reduction to subtle, but measurable, yield reductions); and
- Preparation of a preliminary map demarcating these impact units, which overlays a suitably scaled (e.g., 1:24,000) orthophotoquadrangle base map).

Task Two

In Task Two, the potential for food chain accumulation of metals would be evaluated at sites representing each of the above impact-severity mapping units. The technical staff would determine, from Task One data analysis and field verification, the reference sites to be used in the foodchain studies. The recommended sites would be approved by the MDHES/USEPA.

The recommended laboratory procedures are shown in the right column of Figure 6-1; note that such efforts would utilize the site-specific soil and plant digestates produced by the Task One efforts, as well as livestock tissue sampling (if it can be justified). Analyses of other soil parameters (e.g., organic matter content, liming requirements) would be performed as judged necessary.

Task Three

The third task would involve pilot-scale reclamation studies. Reclamation plots would be established at selected sites (identified

in Task Two) to test the effectivenes of growth medium changes (e.g., liming, soil amendments, fertilizer rates) and use of selected crop/forage species. The objectives of this task are twofold:

- Improved productivity on the affected lands; while
- Prevention of heavy metals accumulation in the terrestrial food chain and simultaneous reduction (if not elimination) of off-site impacts (e.g., due to wind and/or water erosion).

The on-going efforts by the Deer Lodge Valley Conservation District et al. at their reclamation study plots located on the Spangler ranch may serve as a good model for implementing this task. Data currently being generated at the Spangler sites, as well as literature review information, would be utilized by the technical staff to develop and implement a series of reclamation plot studies. The resulting information would be compiled and reviewed, allowing effective evaluation of the relative effectiveness of various remedial technologies during the feasibility study process.

Data generated at the Spangler plots (e.g., seed germination studies) to date are encouraging. If they are continued, and expanded geographically, they will support any site remediation efforts on degraded agricultural lands.

DRAFT

7.0 FAUNA

Four investigations studied animal life in the Silver Bow Creek/Upper Clark Fork River system:

- Macroinvertebrate;
- Bioassay;
- Fish Tissue; and
- Waterfowl.

In general, contaminant impacts were found in these investigations. Insect (macroinvertebrate) communities are definite indicators of extent and severity of contamination. Fish did not exhibit any mortality in water taken from the stream, but adult fish from Warm Springs Ponds did bioconcentrate certain metals. Likewise, waterfowl collected from the ponds' area showed minimal effects.

7.1 MACROINVERTEBRATE INVESTIGATION

7.1.1 Objectives

The types and species of organisms that reside in an aquatic environment are determined by the characteristics of that hydrologic system. In aquatic ecosystems the characteristics that determine the communities inhabiting that system include physical characteristics such as depth, gradient, substrate, and temperature; and chemical characteristics such as dissolved oxygen; presence, absence, or

concentrations of elements and compounds; and pH. The organisms inhabiting any given aquatic system are adapted for living in that particular suite of characteristics. This attribute of organisms has led to the concept of bioindicators--organisms that reflect their environment--and their use for monitoring the physical and chemical characteristics of that environment.

Aquatic macroinvertebrates (large insects) are often chosen for use as bioindicators because of their relative size, ease in collection, and relatively narrow range of tolerance to ecosystem characteristics. For the SBC RI, aquatic macroinvertebrates were selected for use as bioindicators (1) to determine the current biological status of Silver Bow Creek and (2) to provide data on baseline conditions (prior to any remedial action).

A literature review of Silver Bow Creek macroinvertebrates revealed that the existing data were sufficient to achieve the above two goals. However, the data were scattered among several reports by different authors.

To facilitate the post-remediation monitoring and comparisons and to provide a coherent view of the existing biological status of Silver Bow Creek, the SBC RI Work Plan (MultiTech and Stiller and Associates 1984a) recommended a report to achieve three objectives:

- Present and summarize all baseline data available in the literature on aquatic insects for Silver Bow Creek and the upper Clark Fork River;

- Review this data to evaluate the current status of Silver Bow Creek and the upper Clark Fork River; and
- Evaluate this data for use in measuring the success of the remedial actions.

7.1.2 Investigation Methods

Existing data reports were obtained from various sources. Pertinent data from these reports were extracted and reviewed using a screening process to select data usable for meeting the study objectives. The screened data were analyzed against other macroinvertebrate data to evaluate the current status of Silver Bow Creek and the upper Clark Fork River and were summarized to facilitate post-remediation monitoring.

7.1.3 Investigation Findings

The aquatic insect and water quality data review clearly showed that Silver Bow Creek, once devoid of insect life, was beginning to recover in response to treatment of mill wastes. However, the insect communities in this stream were not very diverse or stable, as reflected in wide annual variations in density and taxa. The variation indicates that significant improvement needs to be made before the stream is comparable to other streams in the area.

The Clark Fork River was more fully recovered than Silver Bow Creek. The reactivation of liming at Warm Springs Ponds 2 and 3 in 1963-1964 gave the Clark Fork an eight-to-ten year headstart

on the recovery process in Silver Bow Creek. Like Silver Bow Creek, the Clark Fork has continued to respond to remediation efforts which principally include waste-water treatment of the Weed Concentrator discharge, commencing in 1972. All sampled stations have shown gradually increasing densities and diversity since 1972.

Phillips (1985) suggested that increasing concentrations of trace metals downstream of the Warm Springs ponds was responsible for decreasing numbers of fish per mile. This phenomenon, if it exists, was possibly retarding greater improvement in aquatic insect community composition. The diversity values for sampled stations indicated that all of the stations need to make progress to meet the definition of clean waters (those having diversity values in the 3.0 to 4.0 range).

The historic aquatic insect data for Silver Bow Creek/Clark Fork River is a substantial resource for monitoring future remediation efforts. The data from 1980 through 1984, which includes identification to species, is particularly valuable.

7.1.4 Recommendations

Future collections of aquatic insects should be made using the faunal approach. Faunal surveys are not quantitative studies, but rather are undertaken to discover which species are present and to estimate relative abundance at each station. An important aspect of faunal surveys is to cover a large area of stream-bottom to assure

collection of rare species: rare species may well be the most important in monitoring changes in water quality. The faunal survey approach to sampling will better meet the needs of entities monitoring the progress of remediation efforts than attempts at intensive quantitative studies; they will also be very comparable to the work that has been done since 1972; and finally, they will be more cost-effective than quantitative studies.

7.2 BIOASSAY INVESTIGATION

7.2.1 Objectives

The upper Clark Fork River from the Warm Springs Ponds to Bearmouth (west of Drummond) is classified as a high priority fishery resource (Montana Department of Fish, Wildlife and Parks 1980). However, in spite of this classification, the fishery in the upper Clark Fork River appears to have problems due to contamination of the aquatic system. Densities of trout decline from 1,500-2,500 per mile just below the Warm Springs Ponds to 385-625 per mile below Deer Lodge (Peterman 1985).

Analysis of water samples collected from 14 stations on the river upstream from Milltown Dam, during April to mid-July of 1984 (Phillips 1985), revealed that copper, iron, and zinc were sometimes present at concentrations that exceeded aquatic life criteria. Copper concentrations were the highest of the three and may have been the most limiting. Conditions for aquatic life were reported

to be least favorable in the stream between Deer Lodge and the confluence with Rock Creek. Fish populations were reduced in areas downstream from Deer Lodge where metals concentrations were highest. Bypassing of untreated Silver Bow Creek water into the Clark Fork during periods of high runoff and the erosion of tailings deposited in the floodplain were postulated as the reason for these metals concentrations.

The Surface Water and Point Source, Ground Water and Tailings, and Warm Springs Investigations were designed to identify the sources and transport modes of these metals (See Appendices A, B, and C). However, to document the effect of these metal concentrations on Clark Fork River fish populations, a bioassay study was proposed by the SBC RI Work Plan (MultiTech and Stiller and Associates 1984a).

The study called for a bioassay using eyed rainbow trout eggs through 15 days post-hatch to test the toxicity of contaminants in the Clark Fork River. Taylor Creek was selected as a dilution water source.

7.2.2 Investigation Methods

Previous bioassay studies on the Clark Fork River were performed using the discharge water from Warm Springs Pond 2 as the test water (EG&G 1978; EG&G 1979). These tests showed the discharge had little effect on the tested organism (rainbow trout), but they used the good quality water resulting from treatment at the Warm

Springs Ponds. Since the fish populations below the ponds are good, the bioassay study recommended for the SBC RI was located at Deer Lodge where the fish populations were depressed and the 1984 water quality data indicated poor quality water.

The bioassay test was conducted by a USEPA Bioassay Team from the Environmental Services Division, USEPA, Region VIII, Denver, Colorado. The test was a thirty-day flow-through bioassay conducted on green eggs, eyed eggs, and fingerlings of rainbow trout using Clark Fork River water as the test water and Taylor Creek water, a tributary of the Clark Fork, as the dilution water. The test ran from May 7 to June 6, 1985. Test methods and results are reported in Appendix E, Part 2.

7.2.3 Investigation Findings

Thirty-day flow-through bioassays using green and eyed rainbow trout eggs and fingerling rainbow trout did not show the expected results. Expected high spring runoff with high metals concentrations did not occur in the Clark Fork River during the 30-day study period. Brief rain events flushed copper and zinc into the river system on May 27 and 30 and June 1-2. Metal concentrations in the river following the rain events exceeded calculated chronic and acute copper values for the protection of aquatic organisms, but were not high enough or present in the river long enough to produce significant mortalities of test organisms.

Mortalities in the green-egg test, 100% concentration Clark Fork River, were not significantly different from control (Taylor Creek) mortalities. The 13-day fingerling trout test showed higher mortality in the Clark Fork River water compared to Taylor Creek, which may reflect a reaction of the fingerlings to increased metals concentrations following rain events, but this mortality difference was not statistically significant.

The 30-day eyed egg test reflected a similar sensitivity to metals in the Clark Fork as the fingerling test. Percent hatching and abnormalities did not evidence a toxic effect. Percent mortalities were higher in the Clark Fork River water than in the controls, indicating a possible response to metals toxicity in the river during rain events that exceeded calculated chronic and acute levels predicted to protect aquatic life. If normal spring runoff with its higher metals concentrations had occurred, higher mortalities may have occurred during the test.

7.2.4 Recommendations

A modified series of tests are recommended, to be conducted during a "normal" water year when sufficient snowpack is present to produce a higher runoff than that in 1985. The green-egg test should be either shortened to 10-15 days or not conductd since the embryos appear to be relatively unaffected by changes in metal concentrations after the initial critical period suggested by Birge and Black (1982).

Trout larvae should be tested from post-hatching to 30 days or, if time is restricted, post-swim up to 15 days with an emphasis on lethality and/or growth effects.

7.3 FISH TISSUE INVESTIGATION

7.3.1 Objectives

The consumption of fish residing in the contaminated water of the Silver Bow Creek/Upper Clark Fork River system is a potential pathway of human exposure to toxic elements, but the concentrations of contaminants in the edible fish tissues must be known for a complete feasibility study and risk assessment. Because no fish live in Silver Bow Creek, exposure was not a concern for this part of the site. However, the fish in the Warm Springs Ponds and the upper Clark Fork River may be eaten, and data on them were needed.

Phillips (1982), Van Meter (1974), and Dent (1975) studied metal concentrations in the fish of the upper Clark Fork River. Their research met RI data requirements, so additional studies on this area were not recommended. Studies of fish in the Warm Springs Ponds were recommended, however, as no data existed on them. These fish are not legally consumed, as the Warm Springs Ponds are a catch-and-release area by order of the Montana Department of Fish, Wildlife and Parks (MDFWP); however, their easy accessibility and large size make them tempting to poachers.

The SBC RI Work Plan's design for the Fish Tissue Study (MultiTech and Stiller and Associates 1984a) recommended a certain sampling and analysis methodology; however, after consulting with Wayne Hadley of the MDFWP in Deer Lodge and with the MDHES, the plan of study was modified.

The Work Plan design proposed a sample size large enough to have statistical confidence in the data generated. However, because of the small size of the population to be sampled, an unacceptably high proportion would be removed. Therefore, the consensus sampling plan was not designed to give any statistical significance, but only to assess the general population.

The original sampling plan also was designed to provide a statistical evaluation of metal concentrations in the edible portion of the fish residing in the Warm Springs Ponds. Edible tissue was selected for analysis as providing data for human risk assessment, which was MDHES' highest priority. The consensus plan reduced the statistical evaluation of metals in the edible portion, but added an analysis of metals in liver tissue and an analysis of polyclorinated biphenyls (PCB) and pentachlorophenol (PCP) in the edible portion and reproductive tissues. The liver tissue was included to provide data on the extent of contaminant migration into the fish (liver tissue is known to accumulate metals).

Iron was not recommended in the original work plan as it is a major constituent in vertebrate blood and is differentially distributed

in tissues. Lead was dropped from the work plan analysis list as it was not found in significant amounts in the water analyses.

Additionally, the consensus plan included an analysis of PCB and PCP in fish tissue. These organic parameters were included because Silver Bow Creek was known to receive wastes containing PCP and potentially had received PCB from within the drainage area. Muscle tissue was selected for PCB and PCP analysis, as this is the tissue most often consumed by people. Reproductive tissue was selected for PCB and PCP analysis, as these tissues are high in fats (which are known to accumulate organic pollutants).

The final objectives of the SBC RI Fish Tissue Investigation were as follows:

- Assess metal contamination in the edible portion and livers of fish residing in the Warm Springs Ponds; and
- Assess PCB and PCP contamination in the edible portion and reproductive tissue of fish residing in the Warm Springs Ponds.

7.3.2 Investigation Methods

Ten fish were collected from The Wildlife Ponds, located just below Warm Springs Pond 3: five were used for arsenic, cadmium, copper, and zinc analyses of muscle and liver tissue; and five were used for PCP and PCB's analyses of muscle and reproductive tissues. Metals were analyzed in tissue digests by atomic spectrophotometry. Organics were analyzed in tissue extracts by gas chromotography.

7.3.3 Investigation Findings

7.3.3.1 Metals

Warm Springs Ponds fish muscle and liver tissues were analyzed for arsenic, cadmium, copper, and zinc concentrations. The data then were examined for concentrations greater than those naturally occurring, bioconcentration in and differential concentration between the two tissues, and concentrations above established standards. Arsenic was not significant in any of the four evaluations. The fish did appear to bioconcentrate cadmium in their liver tissue, although not at levels above natural occurrence.

Zinc and copper both appeared to be bioconcentrated by the fish, differentially between the muscle and liver (higher in the liver). Liver concentrations were greater than natural; however, only copper was above the standards. Zinc concentrations were greater in the muscle tissue.

Arsenic

Study results indicate that arsenic concentrations in Warm Springs Ponds fish were not elevated above naturally occurring concentrations, and these fish did not appear to have higher concentrations of arsenic than fish in the upper Clark Fork River. Comparing this study's tissue concentration data to RI water quality data was inconclusive regarding bioconcentration of arsenic by Warm Springs

Ponds fish. Arsenic did not appear to be differentially distributed between fillet and liver tissues, appeared to be in the same concentration ranges as cadmium in fillet and liver tissue, and appeared to be less concentrated than either copper or zinc in both fillet and liver tissues.

Data indicated that arsenic in Warm Springs Ponds fish fillets and livers did not occur at concentrations greater than the USDA's lowest standard of 0.50 µg/g.

Cadmium

Cadmium did not appear to be concentrating at higher than naturally occurring levels in Warm Springs Ponds fish muscle fillets or livers, and cadmium concentrations in Warm Springs Ponds fish fillets did not appear to be higher than cadmium concentrations in the muscle of fish living in the upper Clark Fork River below the ponds. Concentrations in Warm Springs Ponds fish were higher than ambient concentrations of cadmium, indicating some bioconcentration was occurring. Cadmium concentrations were in the same range as arsenic, but were much less than copper or zinc. Cadmium appeared to be concentrating differentially in the tissues tested, occurring at higher concentrations in the liver tissue.

A person would have to eat 6.33 lbs/week of the worst-case fish fillets to reach the FAO/WHO standard of 500 µg/g cadmium per

week. A person would have to eat 0.44 lbs/ week of the worst-case liver tissue to consume the FAO/WHO standard amount.

Copper

Copper did not appear to be elevated above naturally occurring concentrations in Warm Springs Ponds fish fillets, but did appear to be elevated above naturally occurring concentrations in Warm Springs Ponds fish livers. Copper concentrations in Warm Springs Ponds fish fillets appear to be in the same range as muscle from fish living in the Clark Fork River below the ponds. Copper concentrations in Warm Springs Ponds fish fillet and liver tissues were greater than ambient water concentrations, indicating bioconcentration was occurring. Copper concentrations were higher in livers than muscle fillets in the tissues tested. Copper was found at greater concentrations than arsenic or cadmium in both livers and fillets and was higher than zinc in liver tissue.

Warm Springs Ponds fish showed fillet concentrations of copper less than the USDA standard for food of 100 µg/g, but showed liver concentrations of copper greater than the 100 µg/g standard.

Zinc

Fish in the Warm Springs Ponds did not appear to have greater than naturally occurring concentrations of zinc in their fillets. Zinc concentrations in Warm Springs Ponds fish fillets and upper Clark

Fork River fish muscle appeared to be similar. Zinc appeared to be bioconcentrating in both fillet and liver tissue, with both having greater concentrations than was found in the ambient water. Zinc appeared to be differentially distributed, occurring at higher concentrations in tested livers than tested fillets. Zinc was found at higher concentrations than arsenic or cadmium in both fillet and liver tissues. Zinc was higher in concentration than copper in tested fillets, but was lower than copper in tested livers.

All tissues tested for zinc showed concentrations less than the Canadian Food Directorate standard of 100 µg/g.

7.3.3.2 Organics

PCP

PCP was detected in all 10 tissues tested. Fillet concentrations ranged from 0.008-0.024 µg/g wet weight and ranged from 0.301-0.728 µg/g lipid based. Reproductive tissue concentrations ranged from 0.008-0.054 µg/g wet weight and from 1.28-6.58 µg/g lipid based. A 10 kg (22 lb) child would have to consume 91 lbs/day or 27 lbs/day of the worst-case fillet concentration to exceed the USEPA One-Day or Ten-Day and Lifetime Health Advisory No Observed Adverse Effect Levels (NOAEL) for PCP. Literature data comparisons were inconclusive regarding Warm Springs Ponds fish PCP concentrations. PCP did

not appear to be differentially distributed between the muscle fillet and reproductive tissues. PCP concentrations appeared to be less than PCB concentrations in both fillet and reproductive tissues.

PCB

All of five tested fish fillets showed concentrations less than the U.S. Food and Drug Administration (FDA) food standard of 2.0 µg/g. All of five tested reproductive tissues showed concentrations of PCB less than the standard. Literature data indicated PCB contamination of fish is a widespread problem, but since Warm Springs Ponds fish are exposed only to Silver Bow Creek water and local sediments, the source for this PCB contamination must be local. PCB concentrations appeared to be higher than PCP concentrations in the tissues tested. PCB did not appear to be differentially distributed in the tissues tested.

7.3.4 Recommendations

No further studies are recommended for metals or organics in fish tissue.

7.4 WATERFOWL INVESTIGATION

7.4.1 Objectives

The two major groups of potential contaminant receptors and transporters are big game (deer and elk) and waterfowl (ducks and geese). Because big game use of contaminated areas (and therefore, the number of animals potentially affected), is limited, they were not selected for study.

However, the Warm Springs Ponds provide an important year-round waterfowl habitat, specifically managed for waterfowl by the Montana Department of Fish, Wildlife and Parks (MDFWP). This area has been used for waste-water treatment from the mining and milling operations in the basin and has significant quantities of contaminants in the bottom sediments and water of the ponds (See SBC RI Surface Water, Ground Water, and Warm Springs Ponds reports, Appendices A, B, and C). For these reasons, waterfowl from the Warm Springs Ponds were selected for assessing contaminant migration into the biota associated with the Silver Bow Creek site.

The data existing on waterfowl in the site were insufficient to determine the extent of contaminant transport into waterfowl consumed by people. To obtain the data needed to meet the objectives of the SBC RI, a field study of the metal content of Warm Springs Ponds' waterfowl tissue was recommended during the RI study planning stage (MultiTech and Stiller and Associates 1984a).

January was selected to obtain wintering birds; September to obtain juveniles; and November to obtain migrating birds. A single specie (Mallard) was selected to reduce heteorogeneity in sampling. Twenty-five individuals were recommended to increase the power of statistical tests. Age classes were selected, to make adult/juvenile comparisons and to obtain a sample set of individuals that had spent their complete life on the ponds. Steel shot was recommended for collection to allow uncontaminated lead analysis of the tissues. Breast muscle was selected for analysis, as this is the tissue most often consumed by people. Sample preparation and analysis methods were selected to allow a comparison of data with food standards.

The work plan was modified prior to implementation through consultation with the MDFWP. MDFWP had an ongoing sample collection program, and to conserve project resources, these samples were selected for use in the Waterfowl Investigation. This utilization impacted the dates of collection, the number of samples obtained, the method of collection (shotgun with lead shot), the age of each sample, and the chain-of-custody documentation.

Further consultation with MDFWP resulted in the approval of the analysis of five liver tissues for metals and five muscle and five liver tissues for PCP and PCB. Muscle tissue was selected, as this is the tissue most often consumed by people. Liver tissue was selected, as this request to change the scope of the investigation occurred after the dissection of the birds and the liver was the tissue most likely to have comparable literature data. PCP was

selected for analysis as Silver Bow Creek was known to receive waste oil containing PCP. PCB was selected as it is a potential contaminant from the Butte urban area.

The Silver Bow Creek Remedial Investigation Waterfowl Study was designed to meet the following objectives:

- Primary - Provide data that can be used to assess the human risk of consuming Warm Springs Ponds waterfowl; and
- Secondary - Provide data that can be used to assess the migration of contaminants into the biota utilizing the site.

7.4.2 Investigation Methods

Waterfowl samples of several species were collected from February through September 1984. Breast muscle tissues from 39 of the 41 birds collected were tested for arsenic, cadmium, copper, and zinc concentrations, and five liver tissues selected randomly from the 41 birds were tested for the same metals. Five breast muscle tissues and five liver tissues selected randomly were tested for PCP and PCB concentrations. Data from this investigation are reported and compared to literature values in Appendix E, Part 4.

7.4.3 Investigation Findings

7.4.3.1 Metals

Cadmium is the only metal which appeared in elevated concentrations in Warm Springs Ponds waterfowl. The high cadmium concentrations were specifically in liver tissue and not in the muscle tissue.

Arsenic, copper, and zinc concentrations were not elevated above background in either the muscle or liver tissue from Warm Springs Ponds waterfowl, although the copper and zinc differentially concentrated in the liver tissue as compared to the muscle tissue.

Arsenic

Warm Springs Ponds waterfowl did not appear to be concentrating arsenic in their tissues, and none of the samples for which concentrations were calculated had concentrations above the USDA standard of 0.70 µg/g.

Mean arsenic concentrations did not appear to be different between Warm Springs Ponds waterfowl muscle tissue and control samples muscle tissue. Arsenic did not appear to be differentially distributed between muscle and liver tissue in the samples analyzed. No significant differences were noted between mean muscle arsenic concentrations of males vs. females or among the various types: puddle ducks (Antinae), diving ducks (Aythyinae), and geese (Anserinae).

High method detection limits (MDLs) for juvenile samples were caused by low weight sample sizes. Arsenic concentrations in muscle did not appear to be correlated to cadmium, copper, or zinc concentrations in muscle. Arsenic concentrations in the liver appeared to correlate only with copper concentrations in the liver.

Cadmium

Data collected on cadmium concentrations in Warm Springs Pond waterfowl tissues suggested that these waterfowl were concentrating cadmium in their liver tissue: the mean liver cadmium concentrations appeared significantly higher than the mean muscle cadmium concentration for Warm Springs Ponds waterfowl.

The mean muscle cadmium concentrations of Warm Springs Ponds waterfowl did not appear significantly different from the control samples, although puddle duck (Antinae) appeared to have a significantly lower muscle cadmium concentration than did the diving ducks (Aythyinae). No standards are established for cadmium in food; however, based on the FAO/WHO provisional tolerable weekly intake of 500 µg/week, a person would have to eat 13.7 oz. of duck muscle per week of the worst-case muscle sample (1.27 µg/g) to reach the standard, or using the mean muscle concentration of 0.16 µg/g, a person would have to eat 116 oz. (7.3 lbs) of duck muscle to reach the standard.

Cadmium did not appear correlated with any other metal concentrations in either the muscle or the liver.

Copper

Warm Springs Ponds waterfowl did not appear to be concentrating copper in their muscle tissue, and none of the samples analyzed were above the Canadian Food Directorate tolerance level of 100 µg/g. Mean copper concentrations of Warm Springs Ponds waterfowl muscle tissue did not appear to be significantly different from the mean copper concentration of control sample muscle tissue. No significant differences in copper concentrations were detected for age classes, sexes, or subfamily groups. Copper did appear to be differentially distributed between muscle and liver tissue for those samples analyzed. Copper did not appear to be correlated with the other metals, except with arsenic in liver tissue.

Zinc

Zinc concentrations measured in Warm Springs Ponds waterfowl muscle tissue did not exceed the Canadian Food Directorate tolerance level of 100 µg/g. Muscle and liver tissue concentrations of zinc in Warm Springs Ponds waterfowl did not appear to be elevated above normal background.

Mean zinc concentrations in the muscle tissue of Warm Springs Ponds waterfowl did not appear to be significantly different from that

in the muscle tissue of the control samples. However, zinc did appear to be differentially distributed, showing higher values in liver tissue than in muscle tissue. Zinc also appeared to be distributed differently in the muscle tissue by age, sex, and subfamily groups. Zinc showed no correlation with the other metals in either muscle or liver tissue.

7.4.3.2 Organics

PCP

Investigation data indicated that Warm Springs Ponds waterfowl were carrying a body burden of PCP. A 10 kg child would have to consume 5.33 lbs/day of the highest PCP concentration muscle to consume the USEPA One-Day Health Advisory amount of 1.0 mg/day or consume 1.6 lbs/day to reach the USEPA Ten-Day and Lifetime Health Advisory amount of 0.3 mg/day.

PCP in muscle tissue on a lipid basis was related to PCP in muscle tissue on a wet weight basis. PCP and PCB concentrations did not appear to be related. PCP concentrations appeared to be significantly higher in muscle tissue than in liver tissue.

PCB

Three of four Warm Springs Ponds waterfowl muscle tissues analyzed for PCB showed a lipid based residue concentration greater than

the USDA standard for food of 3.0 ppm. The single offsite sample had a PCB concentration of less than the standard.

Literature data suggest that PCB contamination is a widespread problem, with PCB tissue concentrations found above and below those reported for Warm Springs Ponds waterfowl.

PCB residues in Warm Springs Ponds Fish (reported in the SBC RI Fish Tissue Investigation Report, Appendix E, Part 3) indicate a possible local source of PCB contamination.

PCB and PCP did not appear to be related in Warm Springs Ponds waterfowl tissue. PCB concentrations in muscle on a lipid basis were related to PCB concentrations in muscle on a wet weight basis. PCB did not appear to be differentially distributed between muscle tissue and liver tissue.

7.4.4 Recommendations

No recommendations for further study were made.

DRAFT

8.0 NATURE AND EXTENT OF PROBLEMS

The SBC study site is both large and complex, covering nearly 50 river miles. The contaminant problems associated with the site also are diverse. These characteristics necessitated subdividing the site into individual units for study, which resulted in 10 separate investigations, based on the SBC Remedial Action Master Plan (CH2M Hill 1983) and the SBC Work Plan (MultiTech and Stiller and Associates 1984a):

- Surface Water and Point Source Investigation;
- Ground Water and Tailings Investigation;
- Warm Springs Ponds Investigation;
- Algae Investigation;
- Riparian Vegetation;
- Agriculture Investigation;
- Macroinvertebrate Investigation;
- Bioassay Investigation;
- Fish Tissue Investigation; and
- Waterfowl Investigation.

The SBC RI study period extended from November 1984 to January 1986. Individual reports from each of these investigations are appended to this Summary Report. The findings and conclusions of these studies are integrated in this chapter.

Discrete geographic areas have been established for this discussion, based on natural features and functions of the SBC study site as discovered in the separate investigations (See Map 1-1). Features used to identify geographic units included stream morphology (channelized or braided), locations and types of solid waste deposits, lithology, and man-made features. These geographic areas are as follows:

- Metro Storm Drain (MSD) - begins at the outfall from the Weed Concentrator and ends at the confluence with Blacktail Creek.
- Manganese Plant/Colorado Tailings - begins at the confluence of Blacktail Creek and the MSD and ends just below the Colorado Tailings.
- Rocker - begins just below the Colorado Tailings and ends at the Silver Bow railroad siding.
- Ramsay - begins at the Silver Bow siding and ends at Miles Crossing.
- Canyon - begins at Miles Crossing and ends at the Fairmont Bridge.
- Upper Deer Lodge Valley - begins at the Fairmont Bridge and ends at the upper pH shack above the Warm Springs Ponds.
- Warm Springs Ponds - includes the Warm Springs Ponds, the Mill-Willow bypass, and the discharge from the Warm Springs Ponds. It ends at the confluence of Warm Springs Creek and the upper Clark Fork River.
- Upper Clark Fork River - begins at the confluence of Warm Springs Creek and the upper Clark Fork River and extends to the official site boundary at the Kohrs Bridge north of Deer Lodge.

8.1 METRO STORM DRAIN (MSD)

Water found in the MSD had high contaminant concentrations. Silver Bow Creek, which is formed by the confluence of the MSD and Blacktail Creek, also had high contaminant concentrations due to the contaminants from the MSD mixing with the water of Blacktail Creek.

8.1.1 Contaminant Sources

During the SBC RI period, the two major sources of contaminants to the MSD were ground-water inflows, contributing dissolved cadmium and zinc during baseflow conditions; and storm-water runoff, contributing total zinc, iron, arsenic, lead, and cadmium.

Ground-water inflow appeared to acquire its contaminant load from tailings deposits located in the old Silver Bow Creek floodplain, deposited prior to the construction of the MSD. These deposits have since been covered.

Storm water acquired its contaminant load from overland flow. Storm-water sewer discharges were sampled as point sources to the MSD, so the exact location of the contaminant source to the sewer discharges was not observed during the SBC RI. Additionally, much of the metal loading to the MSD during the measured storm runoff event was not measured.

8.1.2 Water Quality

Water in the MSD carried high contaminant loads throughout the study period due to the contaminant-loaded ground-water inflow and surface runoff during high-flow conditions. Aquatic life criteria and drinking water criteria for arsenic, cadmium, copper, iron, lead, and zinc were exceeded on a routine basis by water in the MSD. Ground water in the vicinity of the MSD exceeded drinking water standards for several of the metals of concern.

8.1.3 Environmental Effects

The MSD did not exhibit viable populations of fish, insects, or algae during the study period.

The MSD is located in a completely urban environment. Most of the associated floodplain areas are developed for housing, commercial, or industrial purposes. Those areas not developed are disturbed and support a weedy seral plant community. No significant wildlife use was observed in the immediate MSD area during the RI. However, significant waterfowl and passerine (perching) bird use was evident in wetland areas associated with Blacktail Creek just upstream of the confluence with the MSD. No agricultural land is located adjacent to the MSD.

During the RI, the areas adjacent to the MSD were used for commercial industrial, and domestic purposes. The surface water in the area

was not used, except for occasional casual contact by children. Several wells in the vicinity of the MSD provided water for industrial or domestic irrigation purposes, but no well was appropriated for domestic consumption.

8.2 MANGANESE PLANT/COLORADO TAILINGS

Downstream of the confluence of the MSD and Blacktail Creek the water in Silver Bow Creek was degraded by contaminants from the MSD. Blacktail Creek diluted the contaminants from the MSD to a degree, but additional contaminants contributed in this area further degraded Silver Bow Creek.

8.2.1 Contaminant Sources

Surface-water runoff and ground-water inflow were the two major sources of contaminants to Silver Bow Creek in this area. During periods of high flow, surface runoff from Missoula Gulch contributed loads of total suspended solids (TSS), copper, zinc, iron, arsenic, lead, and cadmium. At low flows, Missoula Gulch contributed copper, zinc, lead, and cadmium.

Ground-water inflows in this reach of Silver Bow Creek appeared to acquire contaminants from several sources. Copper, zinc, sulfate, and cadmium apparently were contributed by ground-water inflow from tailings deposited on the north side of the creek and from upstream

alluvium affected by tailings deposits in the MSD vicinity. Additional copper and iron appeared to be contributed by ground-water inflow from under the Colorado Tailings. When the Metro Sewage Treatment Plant (STP) pumped ground water to dewater the tank foundations, significant quantities of contaminants were contributed to Silver Bow Creek.

8.2.2 Water Quality

Aquatic life criteria and drinking water standards for several of the metals of concern were routinely exceeded in this section of Silver Bow Creek. The normal discharge from the STP was high in phosphorus, but acted to dilute the other contaminants in Silver Bow Creek. Ground water in this area exceeded drinking water standards for several of the metals of concern.

8.2.3 Environmental Effects

Fish occasionally were observed in this reach of Silver Bow Creek just below the MSD/Blacktail Creek confluence. Prior to 1981 no aquatic insects were observed in this stream section; however, each year from 1981 to 1984 insects were collected in this area, but the number of taxa and population sizes significantly fluctuated from year to year and the taxa present indicated severe pollution stress was still occurring. Algae were present in this stretch, but the species present were metal-tolerant.

With the land use adjacent to Silver Bow Creek in this reach limited to commercial, industrial, and abandoned industrial, the terrestrial flora and fauna were severely limited. The disturbed abandoned industrial sites exhibited a weedy seral plant community and the Colorado Tailings had only a single species of plant growing in a small area of the tailings. The rest of the tailings were completely devoid of plant life. Waterfowl occasionally were observed using the STP discharge and Silver Bow Creek below the discharge. A beaver was observed above the Colorado Tailings once during the RI period.

No human use of surface water or ground water occurs in this area, except for occasional direct contact by children playing in the creek. Exposed tailings and waste materials in the Manganese Plant and Colorado Tailings areas are also available for direct contact by persons using these areas for exploration and two-wheeled and three-wheeled motorized recreation.

8.3 ROCKER AREA

Water in Silver Bow Creek from below the Colorado Tailings to Silver Bow contained contaminants during the RI studies, although some settling out of particulate contaminants occurred in this reach during low flows.

8.3.1 Contaminant Sources

No significant contaminant sources were observed in the Rocker area. Due to stream morphology in this reach of Silver Bow Creek, some of the solid metals settled out either as precipitates, particulates, or adsorbates (data were not sufficient to partition the solid load) during low-flow conditions and then were re-entrained during high flow conditions. An abandoned timber-treating plant (which used arsenic and organics as preservatives) at Rocker was evaluated as a potential source. Although elevated arsenic levels were found in the soil, no surface water expression of additional arsenic loading was detected in Silver Bow Creek beyond the plant. Ground water was not sampled below this treatment facility. Organics were not evaluated at this site.

Bank erosion of previously deposited metal-enriched wastes (which line the creek in this section) was postulated as a potential source of contaminants to Silver Bow Creek. This phenomenon was not observed during the SBC RI, as the high-flow conditions which occurred during the study period were not great enough to reach the deposited tailings. The abnormally low runoff period and the present alluvial channel location of Silver Bow Creek prevented significant erosion of tailings during the RI period.

8.3.2 Water Quality

Surface water in this stretch of the creek exceeded aquatic life criteria for several metals on a regular basis throughout the study period. Ground water north of the creek, just downstream of the Colorado Tailings, was found to be contaminated and exceeded drinking water standards for several metals. This area contains covered tailings.

8.3.3 Environmental Effects

No fish were observed in this reach of Silver Bow Creek. Aquatic insects were not sampled in the Rocker area in previous studies, but sites sampled below this area exhibited no aquatic insects prior to 1981, with populations and biomass fluctuating widely from year to year and containing only metal-tolerant species during 1981-1984. Algae were present in this reach of Silver Bow Creek.

Railroad grades flanked both sides of Silver Bow Creek in this reach. In places, willows have recolonized exposed natural alluvium, but the floodplain is extensively disturbed by waste deposits and transportation right-of-ways. A wetlands area with cattails appears at Nissler, but the substrate was not tested for wastes.

Animal use of this reach appeared to be limited to occasional waterfowl use of the creek and wetlands areas and passerine bird use of the willows. A muskrat was observed here during the RI period.

The upland areas in this reach are limited to abandoned industrial, light commercial, and domestic uses, which center in the unincorporated towns of Rocker, Nissler, and Silver Bow. Agricultural use is limited to a single operation which used Silver Bow Creek water for irrigation of some lands and upgradient alluvial wells for other lands. Land irrigated with Silver Bow Creek water exhibited elevated levels of contaminants; this was attributed to historic deposits of wastes mixed in the soil rather than current water use.

8.4 RAMSAY

The Ramsay stream reach, beginning at Silver Bow and ending at Miles Crossing, exhibited some changes in the water quality. Some additonal degradation occurred in this area during high flow events, and a clean water source diluted the contaminants during base-flow conditions.

8.4.1 Contaminant Sources

A major contaminant source in this area during the SBC RI was Browns Gulch during high flow, contributing approximately 21% of the flow, 50% of the TSS, 34% of the total iron, 43% of the total arsenic, and 65% of the total lead to Silver Bow Creek. Browns Gulch flowed through a large waste deposit (Ramsay Flats) before reaching Silver Bow Creek. Based on an evaluation of historical data, this waste deposit was identified as the source of these loadings. Non-point sources were also significant contributors in this reach.

No ground-water input of contaminants to Silver Bow Creek were detected in this reach. Like the upstream reach previously discussed, no significant bank erosion was detected even though the creek flows through 2 miles of continuous waste deposits in this reach.

8.4.2 Water Quality

During base-flow conditions water quality significantly improved in this stream section. The discharge from the wooden pipeline that carries water from Silver Lake to the Weed Concentrator contributed significant flow (averaging 46% during the study period) of good quality water to Silver Bow Creek, resulting in the dilution of contaminants. In spite of this diluting effect, water quality criteria for aquatic life and drinking water standards still were exceeded in this stretch. Cessation of the flow from Silver Lake would significantly degrade the water quality in Silver Bow Creek here. Ground water below the Ramsay Flats deposits exceeded drinking water standards for several of the contaminants of concern.

8.4.3 Environmental Effects

No fish were observed in Silver Bow Creek in this stretch. Aquatic insects were sampled previously at Miles Crossing, but no insects were observed prior to 1981. The observed populations in 1981, 1982, 1983, and 1984 were variable in size and consisted of metal-tolerant species. Metal-tolerant algae species occurred in this stream reach.

Willows have recolonized natural alluvial materials and are the primary natural terrestrial features of the Silver Bow Creek floodplain in this area. Significant portions of the floodplain in this area are covered by unvegetated waste materials. Agricultural activities are limited primarily to upland areas and the floodplain and benches of Browns Gulch above the Ramsay Flats. Waterfowl use of this area was limited.

The most significant land use within the floodplain of the creek between Silver Bow and Miles Crossing are railroad right-of-ways. Tailings deposits effectively have prevented other uses. Above the Ramsay Flats, the Browns Gulch floodplain is used for agriculture. The town of Ramsay was sited on the uplands above the Ramsay tailings deposits.

8.5 SILVER BOW CREEK CANYON

From Miles Crossing to the Fairmont Bridge, Silver Bow Creek cuts through a small canyon. This area is characterized by very small waste deposits, relatively high gradient, a narrow floodplain, and the input of German Gulch.

8.5.1 Contaminant Sources

No significant contaminant sources were detected in this stream reach. The relatively high gradient through this area and the narrow flood plain prevented significant deposits of tailings.

8.5.2 Water Quality

Contaminant concentrations in this reach of Silver Bow Creek were diluted by the flow addition of German Gulch, a relatively pristine tributary of Silver Bow Creek. Contaminant levels in Silver Bow Creek remained high enough in this area to exceed aquatic life criteria in spite of the dilution by German Gulch. However, the dilution appeared to be effectively reducing contaminant levels to below drinking water standards for all the contaminants except iron.

Ground water was sampled just below Miles Crossing in two wells finished in the alluvium of the Silver Bow Creek floodplain. One of the two wells showed slightly elevated concentrations of metals and sulfates, but no sources were determined.

8.5.3 Environmental Effects

Fish were observed in Silver Bow Creek below the input from German Gulch. Macroinvertebrates (insects) were detected in this stream reach from 1975 to 1983, but not prior to 1975. The density and number of species present have been slowly increasing since 1975, but year to year fluctuations indicate that the stream fauna were still stressed by metal concentrations. Algae species tolerant to metal contamination occurred throughout this reach.

The relatively high gradient of Silver Bow Creek through the canyon has limited floodplain development. Willows occur where the moisture

regime is appropriate. Waste deposits are limited primarily to small, moving point bars which have little impact on terrestrial riparian (river bank) vegetation.

Adjacent upland areas are forested with Douglas fir and spruce (at higher elevations) on the northerly exposures with grass-shrublands (mostly western wheatgrass and rabbitbrush) on the southerly exposures. Big game species such as deer and elk utilize these upland zones for forage and cover. Waterfowl use of the riparian zone is limited due to the gradient and its effects on the riparian vegetation community. No agricultural lands are in the Canyon area proper, but subirrigated and surface irrigated (using German Gulch water) lands are present in the Silver Bow Creek floodplain between the mouth of the Canyon and the Fairmont Bridge.

Railroad right-of-ways are the most significant human use of the Silver Bow Creek floodplain from Miles Crossing to the Fairmont Bridge. Between the canyon outlet and the bridge, some floodplain land is used for agriculture. The upland areas of the canyon are used for grazing (both domestic and wild) and timber production.

Fairmont Hot Springs, a destination resort, is located approximately one mile from the Fairmont Bridge. This resort features a golf course, two swimming pools which utilize hot springs water, and lodging in a motel and camping park.

8.6 UPPER DEER LODGE VALLEY

Water quality in Silver Bow Creek from the Fairmont Bridge to the Warm Springs Ponds improves through chemical reactions with underlying carbonate alluvium and small, good quality tributary additions. Riparian vegetation and associated land uses are significantly impacted in this area by waste deposits.

8.6.1 Contaminant Sources

No significant sources of contaminants to Silver Bow Creek were detected in this stream reach. Adjacent bank waste deposits were potential sources through erosion during high run-off, but this phenomenon was not observed during the RI study period.

8.6.2 Water Quality

Surface water quality improved from upstream to downstream in this stream reach during the SBC RI. This improvement was attributed to the carbonate nature of the underlying alluvium and small tributary additions. Aquatic life water quality criteria for several contaminants were exceeded in this reach in spite of the general improvement, but only the secondary drinking water criteria for iron was exceeded during the SBC RI. Ground-water quality in the alluvium of this reach of Silver Bow Creek showed no evidence of contamination.

8.6.3 Environmental Effects

No fish were observed in this stream reach during the SBC RI. Macroinvertebrates were first detected in this stream section in 1975. Populations and number of species have increased since 1975 (through 1984), but the species present and yearly fluctuations indicated that the aquatic insect community were still stressed. Algae were present in this stream reach.

Riparian vegetation is severely affected in this stream reach by waste deposits. The lowered gradient of Silver Bow Creek in this area produced widespread waste deposits that have limited riparian vegetation growth. Additional upland areas were affected by the historical use of Silver Bow Creek water for irrigation purposes. Waterfowl use this area occasionally.

The most significant use of the Silver Bow Creek floodplain in this reach is for gravel quarrying. Several operating pits are located in this area, as are several abandoned pits. No agriculture occurs in the floodplain due to the extensive tailings deposits, but extensive agricultural activity is present above the floodplain. Some rural housing is located in the floodplain in this area, centered in Gregson.

8.7 WARM SPRINGS PONDS

The Warm Springs Ponds further improve the water quality of Silver Bow Creek by allowing suspended sediments and precipitates to settle. During the SBC RI lime was added to the pond input and past management practices included liming to increase pH and facilitate precipitation of metals.

8.7.1 Contaminant Sources

The Warm Springs Ponds were a potential source of contamination during the SBC RI, but additional contaminant loading to the upper Clark Fork River was not identified. The ponds reduced contaminant loads (except for sulfate) from Silver Bow Creek before releasing the water to the upper Clark Fork River. Sulfate loads increased through the pond system.

Two pathways of contaminant migration were identified for the ponds; catastrophic failure and ground-water movement. The pond structures were designed to withstand a 100-year flood. The Probable Maximum Flood would cause catastrophic failure of pond structures, washing 70 years' accumulation of sediments downstream.

Ground water below the pond system exhibited a contaminant plume moving toward the upper Clark Fork River. However, increased loads of contaminants in the river were not detected.

8.7.2 Water Quality

Water quality improved in Silver Bow Creek as a result of pond influences during the SBC RI. However, pond efficiency was not high enough to affect contaminant concentration reductions to below aquatic life criteria all of the time. During SBC RI high-flow events, a majority of the copper, zinc, and cadmium; less than half of the iron, arsenic, and TSS; and most of the lead were removed from Silver Bow Creek by the pond system. During low flows, most contaminants except arsenic were removed almost completely by the ponds.

During very high flow events, the input structure to the Warm Springs Ponds is bypassed as a management practice to avoid pond system upset. During these events, some of the flow from Silver Bow Creek goes into the ponds and the rest is bypassed to the Mill-Willow Bypass untreated. During the SBC RI this bypass occurred once.

8.7.3 Environmental Effects

The pond system supports fairly diverse and complete aquatic floral and faunal communities. Fish lived in the small wildlife ponds which are supplied with water from Pond 3. These fish showed no obvious effects from living in this water, but tissue analyzed during the SBC RI indicated the fish were carrying higher than normal burdens of copper and zinc in their livers. Fish muscle tissues tested did not show concentrations above standards for food.

Aquatic insect populations in the pond system were not extensively studied in the historical literature reviewed for the SBC RI. Above the channel from Silver Bow Creek, the Mill-Willow Bypass was sampled and exhibited a healthy aquatic insect community. Insect populations in the wildlife ponds were healthy enough to support the indigenous fish.

Algae were present in the pond system during the SBC RI. RI data suggested that algae played a role in metal transport out of the ponds during late winter and early spring.

The ponds supported a significant riparian community of cattails where water levels were continuously above the sediments. Willows were also a significant component of the terrestrial vegetation. In Pond 1, where areas of sediments were dewatered, a sparse weedy plant community was found.

Waterfowl were the most important component of the ponds' fauna. These ponds serve as a major Montana migration stopover for geese and ducks (over 100,000 snow geese have been reported) and are a locally significant area for waterfowl production. The Montana Department of Fish, Wildlife and Parks operates the pond area as a Wildlife Management Area for waterfowl under a lease agreement with the Anaconda Minerals Company. SBC RI tests of waterfowl tissues indicated that the muscle tissue did not have concentrations of arsenic, cadmium, copper, or zinc greater than food standards,

but that the liver tissues had cadmium concentrations greater than expected background.

The most significant use of the Warm Springs Ponds area is for recreation. The fish in the Wildlife Ponds are available to sportsmen on a catch and release basis, and the areas around Pond No. 2 are open for waterfowl hunting. Other uses include recreational bird watching and pond management activities.

8.8 UPPER CLARK FORK RIVER

In this stream reach aquatic life criteria for several contaminants were exceeded, riparian vegetation was affected by tailings deposits, and agricultural lands were impacted by the historic use of Clark Fork River water.

8.8.1 Contaminant Sources

Bank erosion of deposited tailings, overland (tailings) run-off, and ground-water leaching of tailings are potential sources of contaminants in this part of the site; however, these sources' contributions were not observed during the SBC RI. The sparse sampling of high-flow events may have limited observation of typical bank erosion. Occasional bypasses of the Warm Springs Ponds was identified as a source to the upper Clark Fork River. No other sources or potential sources of contaminants were identified for this part of the site.

8.8.2 Water Quality

During the SBC RI, water quality in the upper Clark Fork River did not change significantly. Water quality in this stream reach was primarily determined by the quality of the discharge from the Warm Springs Ponds and tributary streams (Warm Springs Creek, Lost Creek, Modesty Creek, Racetrack Creek, Dempsey Creek, Caribou Creek, Powell Creek, Petersen Creek, Taylor Creek, and Cottonwood Creek).

Studies prior to the SBC RI have shown a decrease in water quality with distance from the Warm Springs Ponds, especially during spring run-off periods (Phillips 1985).

Aquatic life water quality criteria for copper and zinc were exceeded in this stream reach during the spring runoff period, but this was attributed to upstream contributions rather than sources in this reach. Drinking water standards were not exceeded in this stream reach.

8.8.3 Environmental Effects

Fish populations were healthy below the Warm Springs Ponds but declined with distance from the ponds, changing by an order of maginitude. A bioassay test performed at Deer Lodge during the spring runoff period of 1985 did not detect any significant effects to fish growth and survival from the Clark Fork River.

Increased contaminant loads from bank erosion during the spring and occasional bypass of the Warm Springs Ponds were hypothesized as the causes of fish population declines from Warm Springs to Deer Lodge. During the SBC RI the spring, runoff was abnormally low and bank erosion was not observed, perhaps affecting the results of the bioassay study. Previous studies of contaminant levels in fish tissue from this reach (Phillips 1982) concluded that tissue concentrations of the contaminants tested did not exceed food standards.

The number of taxa, diversity, number of organisms, and biomass of aquatic insects increased in this stream reach from 1972 to 1984. However, aquatic insect measurements followed a pattern similar to fish populations, as these measurements declined with distance from the Warm Springs Ponds (Chadwick and Associates 1984).

Algae were a major component of the flora of the river in this section. Riparian vegetation in this reach has been damaged by waste deposits. Due to sediment contributions from tributaries, some of the older waste deposits have been overlain by new sediment deposits, complicating their identification. Tailings deposits and sediment deposits have been moved and mixed by natural fluvial processes, affecting riparian vegetation. Historic use of Clark Fork River water for irrigation affected agricultural lands in this reach, limiting production on some lands and completely sterilizing the soil at certain sites.

The wildlife community of this area is typical of western Montana riverine environments: waterfowl, big game (such as deer), fur-bearers, and passerine birds.

Agriculture is the largest land use in the floodplain of the upper Clark Fork River. Pasture and cultivation for hay are the two most important agricultural uses. Outside of Deer Lodge, rural housing is found in the floodplain. The Clark Fork River bisects the city of Deer Lodge, where adjacent land use includes housing, industrial, abandoned industrial, and commercial. The study site ends at the Kohrs Bridge, part of the Grant Kohrs Historic Site managed by the U.S. Park Service.

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